National Park Service
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Natural Resource Program Center

Northern Great Plains Network Vital Signs Monitoring Plan

Natural Resource Report NPS/NGPN/NRR—2010/186





ON THE COVER

Photographs clockwise from upper left: Sunrise at Fort Union Trading Post National Historic Site, ND; Native prairie at Theodore Roosevelt National Park, ND; Sunset over the Little Missouri River at Theodore Roosevelt National Park, ND; Ruins of the old hospital at Fort Laramie National Historic Site, WY; Silky milkvetch (*Astragalus sericoleucus*) at Agate Fossil Beds National Monument, NE. All photos were taken by Northern Great Plains Network staff.

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Executive Summary

The condition of natural resources in parks and other units of the National Park Service (NPS) is fundamental to this agency's mission to manage park resources "unimpaired for the enjoyment of future generations." Park managers are increasingly confronted with complex and challenging resource management issues and need a broad-based understanding of the status and trends of park resources for the long-term protection of park ecosystems. The National Park Service has initiated a long-term ecological "Vital Signs" monitoring program to provide the minimum infrastructure needed to track the overall condition of natural resources in parks and to provide early warning of situations that require intervention. The focus of the program is on assessing status and trends at the level of individual parks, with broader regional or national inference a secondary goal when feasible. This multi-disciplinary monitoring program will create broad applications for management decision-making and park planning, increase our knowledge of park ecosystems, and promote public understanding of park resources.

> ***What are Vital Signs?***
>
> *Vital Signs are a subset of physical, chemical, and biological elements and processes of park ecosystems selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.*

To facilitate collaboration and information sharing among parks with similar natural resource issues, and to obtain economies of scale in inventory and monitoring, the NPS organized the more than 270 parks with significant natural resources into 32 ecoregional Networks. The Northern Great Plains Inventory and Monitoring Network (NGPN) includes 13 park units in North and South Dakota, Nebraska, Wyoming, and eastern Montana. The Network includes Agate Fossil Beds, Devils Tower, Jewel Cave, and Scotts Bluff National Monuments (AGFO, DETO, JECA, and SCBL); Fort Laramie, Fort Union Trading Post, and Knife River Indian Villages National Historic Sites (FOLA, FOUS, and KNRI); Badlands, Theodore Roosevelt, and Wind Cave National Parks (BADL, THRO, and WICA); Missouri National Recreational River (MNRR); Niobrara National Scenic River (NIOB); and Mount Rushmore National Memorial (MORU). The NGPN monitoring program is designed to complement, not replace, existing park and other agency monitoring programs. Funding for the program supports a core of professional Inventory and Monitoring (I&M) staff who conduct the day-to-day activities of the Network. The core staff collaborates with staffs from the 13 parks and other programs and agencies to implement an integrated long-term program for monitoring high-priority Vital Signs.

The program is designed to ensure that monitoring addresses critical information needs of park managers and produces ecologically relevant and scientifically credible data that are accessible to park managers, planners, and other key audiences. The monitoring program will leverage its funding through collaborative partnerships with other programs, agencies, and academia. This monitoring plan, the result of a multi-year investment in program development, is the foundation of the NGPN's monitoring program.

The first planning steps involved compiling and reviewing relevant scientific information, conducting detailed park scoping to identify the most important resources and issues for each park, and assessing current monitoring by parks and other programs to prioritize gaps in current monitoring and identify opportunities for integrating information across programs. Chapter 1 and associated appendices summarize the results of these scoping efforts and provide an overview of the NGPN parks. Chapter 1 also summarizes the policy and management context for the Network's monitoring program, including its goals and broad objectives.

Goals of Vital Signs Monitoring

- *Determine the status and trends in selected indicators of the condition of park ecosystems to allow managers to make better informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources*

- *Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management*

- *Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments*

- *Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment*

- *Provide a means of measuring progress toward performance goals*

The second step was to develop conceptual ecological models of the predominant ecosystems associated with Network parks (Chapter 2), including key ecosystem drivers, stressors, and processes. In addition to helping prioritize monitoring objectives, these models will help interpret and communicate monitoring results to park management, our scientific partners, park visitors, and the public. Using the results of the early planning and design work, Network staff, other NPS experts, and regional scientists ranked and prioritized potential Vital Signs. The result is a list of high-priority Vital Signs (Chapter 3) that will be monitored by the NGPN, park staff, or collaborating programs and agencies. The NGPN will use existing programs and data to address many Vital Signs to help put I&M-collected data into context and to leverage the core Network funding and staff.

Chapter 4 provides an overview of how Vital Signs sampling locations are chosen and includes the revisit schedule for sampling each location through time (i.e., sample design). The Network will use data collected from probability samples or censuses (for remote sensing protocols) when possible. For expensive monitoring limited to one or two locations per park we will use nonprobabilistically selected index sites; supplemental sampling and model-based inference will be needed to estimate park-wide trends in these cases. Where possible, sampling for Vital Signs will be co-located in space and time to improve efficiency and depth of ecological understanding.

Monitoring protocols detail how data are to be collected, managed, analyzed, and reported, often through collaboration with other programs. Over the next several years, Network staff and collaborators will develop 12 monitoring protocols (Chapter 5) that address Vital Signs for which staff will play a lead role in field data collection as well as high-priority Vital Signs (e.g., air quality) being monitored by other programs. Of the 12 protocols, the Network's top priorities focus on plant community/vegetation composition and structure, and water quality.

Vital Signs to be monitored by the Northern Great Plains I&M Network.

Symbols: + = NGPN will develop protocols and implement monitoring using funding from the Vital Signs or water quality monitoring program. ● = Vital Signs being monitored by a Network park, another NPS program, or another federal or state agency using other funding. The Network will collaborate with these other efforts. ◊ = Parks where these Vital Signs are not currently being monitored but likely will be in the future. Shading = Vital Signs monitored by NGPN parks, other NPS entities, or other agencies.

Vital Sign Category	Vital Sign	AGFO	BADL	DETO	FOLA	FOUS	JECA	KNRI	MNRR	MORU	NIOB	SCBL	THRO	WICA
Air and Climate	Ozone	◊	●	◊							◊	◊	●	●
	Wet and Dry Deposition	◊	●	◊							◊	◊	●	●
	Visibility and Particulate Matter		●										●	●
	Air Contaminants		●										●	●
	Weather and Climate	●	●	●	●	●	●	●	●	●	●	●	●	●
Geology and Soils	**Stream and River Channel Characteristics**	+	+	+	+	+		+	+	+	+	+	+	+
	Cave Meteorology						+							+
Water	Groundwater Dynamics	●		●			●				●	●		●
	Surface Water Dynamics	●	●	●	●	●		●	●	●	●	●	●	●
	Surface Water Chemistry	+	+	+	+		+	+	+	+	+	+	+	+
	Cave Water Chemistry						+							+
	Aquatic Contaminants	+	+	+	+		+	+	+	+	+	+	+	+
	Aquatic Microorganisms	+	+	+	+		+	+	+	+	+	+	+	+
	Aquatic Macroinvertebrates	+	+	+	+		+	+	+	+	+	+	+	+
Biology Integrity	**Exotic Plant Early Detection**	+	+	+	+	+	+	+	+	+	+	+	+	+
	Forest Insects and Diseases			●			●			●				●
	Riparian Lowland Plant Communities	+		+	+			+	+		+	+	+	+
	Upland Plant Communities	+	+	+	+	+	+	+	+	+	+	+	+	+
	Land Birds	+	+	+	+	+	+	+	+	+	+	+	+	+
	Raptors		●	●					●				●	●
	Prairie Dogs		●	●								+	●	●
	Ungulates		●										●	●
	Piping Plovers and Interior Least Terns								●		●			
	Black-footed Ferrets		●											●
	Pallid Sturgeon								●					
Human Use	Treatments of Exotic Infestations	●	●	●	●	●	●	●	●	●	●	●	●	●
	Visitor Use	●	●	●	●	●	●	●	●	●	●	●	●	●
Landscapes (Ecosystem Pattern and Processes)	Fire and Fuel Dynamics	●	●	●	●	●	●	●	◊	●	◊	●	●	●
	Land Cover and Use	+	+	+	+	+	+	+	+	+	+	+	+	+
	Extreme Disturbances	+	+	+	+	+	+	+	+	+	+	+	+	+
	Soundscape	+	+	+	+	+	+	+	+	+	+	+	+	+

Managing data and information is a central mission of the NGPN I&M Program involving all Network staff. The Network will follow procedures outlined in the NGPN Data Management Plan and summarized in Chapter 6 to assure and maintain data integrity and availability. This data management strategy addresses quality-assurance procedures during acquisition, verification, validation, analysis, and dissemination of monitoring data. The data management strategy also focuses on storage, maintenance, and security issues that apply to all stages of the data flow.

To make results of monitoring useful to park managers and other audiences, Network staff must employ statistically defensible analyses and communicate the results efficiently (Chapter 7). Network staff will compile, analyze, synthesize, and report monitoring results, including data collected by others, to make the data more available and useful. The Network internet and intranet websites will be used as a clearinghouse to disseminate technical reports, briefing statements, monitoring protocols, and links to additional sources of data and information.

The NGPN relies on two groups to provide program oversight and guidance, the Board of Directors (BOD) and the NGPN Technical Committee (Chapter 8). The Network is also accountable to the NPS Associate Director through the Regional and National I&M Program Leaders. Superintendents of NGPN parks are members of the BOD on a rotating basis; five superintendents on the Board at a time. The Regional I&M Coordinator for the Midwest Region and the Network Coordinator are permanent board members. The BOD makes decisions regarding the development and implementation of the Network's monitoring strategy, including approval of annual budgets, work plans, and staffing plans, and promotes overall accountability for the monitoring program. The Technical Committee, which includes the Network Coordinator, a park resource specialist from each park, and the Regional Coordinator, helps develop the Network's work plan, ensures that Network activities dovetail with park activities, and provides input for issues that require BOD approval. The NGPN Charter (Appendix F) outlines these various roles and responsibilities.

The NGPN I&M core staff will include at least seven permanent full-time staff, two term positions, and seasonal staff for field crews and other activities. The core staff, Network park staff, and external collaborators will play critical roles in implementing this monitoring plan (Chapters 8 and 9). Approximately 70% of the Network I&M budget will be spent on salaries; including staff time and other expenditures, at least one-third of the budget will be used for data and information management and reporting (Chapter 10). Partnerships with other NPS programs (e.g., Air Resources Division) and other government and nongovernment programs will provide the I&M Program with necessary expertise and support to ensure that high-quality data are collected and interpreted appropriately.

Acknowledgements

This plan was developed in partnership with natural resource managers, superintendents, and other staff of the 13 parks of the Northern Great Plains (NGPN) Network. They continually provided expert input and guidance to ensure that the NGPN monitoring program will help their mission to conserve the unique resources of these parks.

This plan was shaped heavily by Dan Licht, former Network Coordinator. Dan led the Network during initial selection of Vital Signs and prioritization of protocols; Chapters 1 and 3, and sections of Appendices A and B are built partly on drafts he wrote. Besides developing the NGPN's Plant Communities monitoring protocol, Amy Symstad of the USGS has offered continued help and insights affecting all aspects of this plan. She has played a major role in the development of this Network. Other non-NPS personnel who offered critical support and insights include Tom Juntti and Dan Uresk, U.S. Forest Service, as well as many other NPS and non-NPS experts who formally or informally helped the Network select Vital Signs and begin to develop monitoring protocols. Information on aquatic resources and stressors was provided by Nels Troelstrup, South Dakota State University. Janice Faaborg provided technical editing of this document. Amy Hess of Desktop Studio provided the graphic design and layout for the publication.

We benefited tremendously from the ideas and documents produced by other NPS I&M Networks. Many of our chapters heavily utilize text and examples from other Networks' plans. Staff from other Networks provided invaluable comments and advice on sections of the plan, on sampling design, or on other aspects of our monitoring plan and protocols, particularly Mike DeBacker, Bill Route, Steve Garman, and Billy Schwieger.

Regional and National NPS I&M staff provided continued support, direction, and input to help us complete this plan, particularly Carmen Thomson, John Gross, and Tom Philippi. John Gross, Tom Philippi, and Roy Irwin provided invaluable comments about drafts of some chapters of the plan. Finally, we are extremely grateful to Steve Fancy, NPS National Monitoring Program Leader. The existence of the NGPN I&M Network, the completion of this plan, and our initial steps toward implementation have been possible because of his dedication, vision, guidance, and help.

All photos in the plan, unless otherwise noted were taken by NGPN staff. Most of the NGPN images were taken by Dan Licht. We thank Doug Backlund and Jim Pizarowicz for giving us permission to use their photos.

Chapter 1
Introduction and Background

Sunrise at Knife River Indian Villages National Historic Site

The U.S. National Park Service (NPS) has a clear mandate to conserve resources of National Parks and other NPS units in a manner that leaves them "unimpaired for the enjoyment of future generations" (16 U.S.C. 1 § 1; Appendix A). To fulfill this mandate, NPS managers in the Northern Great Plains Network (NGPN) need to know the status (current conditions) and trends (directional changes across time) of the natural resources they are charged with protecting. Like other NPS units across the U.S., the Network is developing a long-term ecological monitoring program to help managers evaluate current status and trends in the condition of park resources. The monitoring program outlined in this document will help alert Network managers to resource degradation, and assess whether current management actions are effectively maintaining or restoring these resources. Managers will also use this information to help other agencies and groups make decisions that benefit park resources.

In this chapter, we provide the context for long-term monitoring in the NGPN.

Introduction to the Northern Great Plains Network

The Network includes 13 NPS units, primarily in North and South Dakota, Nebraska, and Wyoming (Figure 1-1; NGPN 2006; Fort Union Trading Post National Historic Site straddles the North Dakota/Montana border), including four national monuments (NM), three national historic sites (NHS), three national parks (NP), a national recreational river (NRR), a national scenic river (NSR), and a national memorial (NMEM). Eleven parks are in the Midwest Region of the NPS; Fort Laramie NHS and Devils Tower NM are in the Intermountain Region. These 13 parks vary widely in size, amount of visitor use, and management context (Table 1-1).

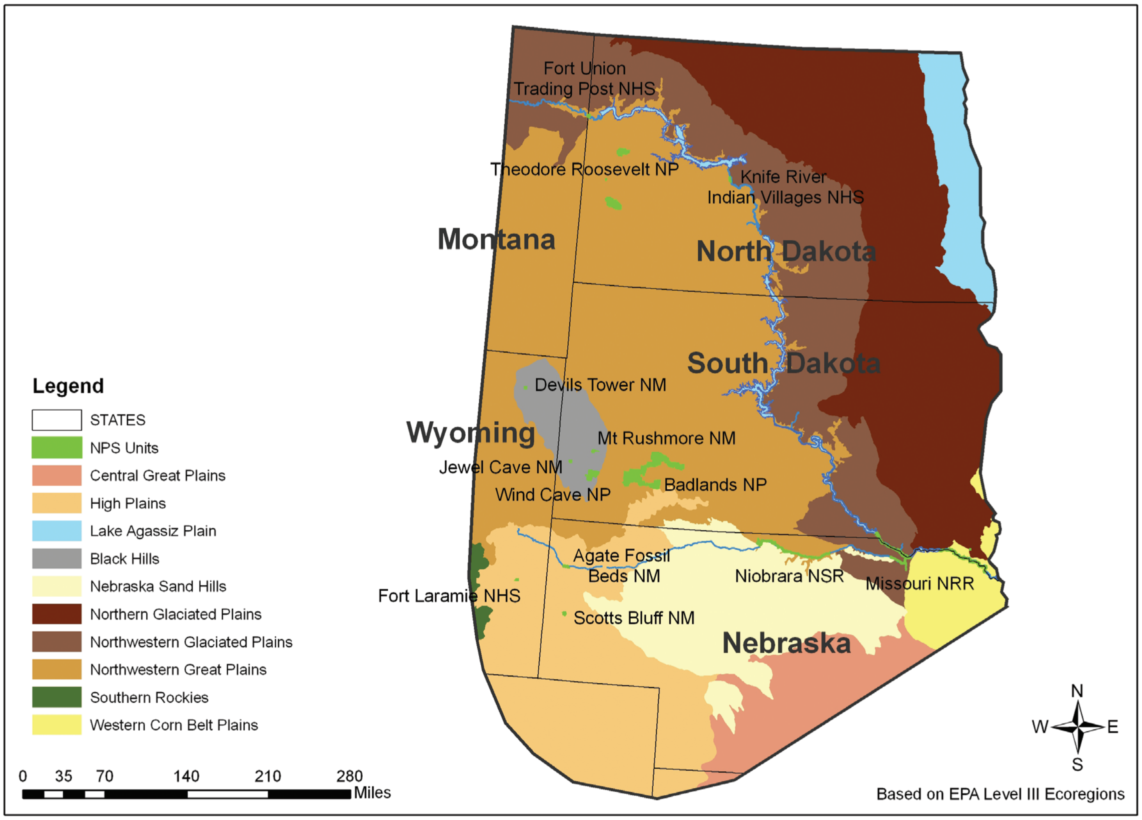


Figure 1-1. Parks and ecoregions of the Northern Great Plains Network (NGPN).

The NGPN units manage cultural and natural resources of regional, national, and global significance. The 13 parks include specific sites that were (and still are) of high importance to Native Americans of the region (e.g., Knife River Indian Villages and Devils Tower) as well as sites that played critical roles in Euro-American westward expansion (Fort Laramie, Fort Union, and Scotts Bluff). The Network supports unique natural resources, including large areas of northern mixed-grass communities at several parks (e.g., Agate Fossil Beds NM and Badlands NP) and the second largest area of old-growth ponderosa pine in the region (Mount Rushmore NMEM). Wind Cave, Badlands, and Theodore Roosevelt NPs are occupied by diverse herds of ungulates, including large herds of bison and four or five other ungulate species. Network parks manage two of the four longest caves in the world (Jewel Cave and Wind Cave), remote areas where air pollution, light, and human noise are not much higher than they were several hundred years ago (e.g., Badlands Wilderness Area), and prairie rivers (Missouri, Niobrara, and others) of high ecological importance in this semi-arid region. These rivers include undammed reaches that are rare in the region (Little Missouri River at Theodore Roosevelt NP). Long-term monitoring will provide information essential for maintaining these unique resources.

Table 1-1. Overview of parks in the Northern Great Plains Network (NGPN).

Park	Authorized[a]	Acres (2006)[b, c]	Visitors (2006)[b]
Agate Fossil Beds NM (AGFO)	1965	3,058	13,521
Badlands NP (BADL)	1929	242,756	858,952
Devils Tower NM (DETO)	1906	1,347	337,508
Fort Laramie NHS (FOLA)	1938	833	41,016
Fort Union Trading Post NHS (FOUS)	1966	444	13,900
Jewel Cave NM (JECA)	1908	1,274	97,547
Knife R. Indian Villages NHS (KNRI)	1974	1,758	24,704
Missouri NRR (MNRR)	1978	67,452	167,960
Mount Rushmore NMEM (MORU)	1925	1,278	2,688,211
Niobrara NSR (NIOB)	1991	23,074	60,397
Scotts Bluff NM (SCBL)	1919	3,005	98,352
Theodore Roosevelt NP (THRO)	1947	70,447	441,937
Wind Cave NP (WICA)	1903	28,295	828,326
Total		445,021	5,672,331

[a]Year the unit was originally authorized, proclaimed, or established. Many units had subsequent expansions, modifications, or redesignations.

[b]From http://www2.nature.nps.gov/stats/homebody.htm, NPS Public Use Statistics Office.

[c]Defined as acres within the park boundary, which may differ from the actual fee acres owned by the federal government.

The Need for Long-term Monitoring in the NGPN

Types of Monitoring

Monitoring is the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting management objectives (Elzinga et al. 1998). This plan focuses on long-term monitoring to assess multi-year and multi-decade trends in resource attributes of each park. This plan does not deal with implementation or compliance monitoring, which examines whether actions specified by a natural resource management plan are being implemented, or short-term effectiveness monitoring, which assesses whether individual management actions produce desired effects in altering or maintaining resource conditions. However, the NGPN's long-term monitoring will examine broader scale management effectiveness to determine whether the collection of individual management actions are helping maintain or restore park resources to desired conditions in the face of stressors such as climate change (Nichols and Williams 2006).

Legislation and Policies That Require Monitoring

All NPS units, including NGPN parks, are mandated to track the condition of their natural resources. The NPS Organic Act of 1916 (16 U.S.C. 1 § 1) established and defined the mission of the NPS (Appendix A provides more details about legislation, policy, and executive guidance relevant to natural resource monitoring in the NPS). Through the Organic Act, Congress implied the need to monitor natural resources and guarantee unimpaired park resources:

> The service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified … by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.

In 1978, this protective function of the NPS was further strengthened when Congress amended the Organic Act to state:

> …the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established.

The National Parks Omnibus Management Act of 1998 directed the NPS to "undertake a program of inventory and monitoring of National Park System resources to establish baseline information and to provide information on long-term trends in the condition of the National Park System resources" (P.L. 105-391). This directive is echoed in the agency's own policy stating that the agency shall "define, assemble, and synthesize comprehensive baseline inventory data describing natural resources" and "use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals" (NPS 2006:40). The NPS management policies also clearly direct parks to conserve species native to the parks, the natural structure and condition of parks, and the natural processes that affect and maintain these resources (NPS 2006:42-49). The enabling legislation and mission statements for most units in the NGPN emphasize protection of natural resources as a primary or secondary focus (NGPN 2006). To assess whether they are meeting the requirements of these laws and policies, parks need information from scientifically credible long-term monitoring.

Finally, long-term monitoring will help Network parks comply with the Government Performance and Results Act (GPRA) of 1993 that directs agencies to establish measurable objectives and report their progress. The Inventory and Monitoring (I&M) Program is an essential component for addressing NPS GPRA goals focusing on preservation and protection of park resources (Table 1-2) and defining unit-specific GPRA goals. For example, at Badlands NP prairie dogs are a park-specific priority under GPRA goal Ia2b ("Species of Management Concern"). Long-term monitoring of prairie dogs will help the park assess whether it is meeting its management objectives.

Table 1-2. Relevance of monitoring by the NGPN to Government Performance and Results Act (GPRA) goals.

NPS Strategic Plan Mission Goals (numbers refer to GPRA goal)	NGPN I&M Role in Meeting Goal
Ia1. Disturbed Lands/Exotic Species – 10.1% of targeted disturbed park lands are restored and exotic vegetation on 6.3% of targeted acres are contained.	All parks have exotic vegetation and disturbed lands. Monitoring will track park-wide plant community composition and assist with detection of new exotic species.
Ia1. Land Health – Park management plans may specify what percentage of acres or shoreline miles should meet desired conditions for wetland, riparian, or upland areas.	Network parks will use information collected by the I&M Program, in combination with other information, to assess and report the percentage of lands that are in good condition.
Ia2. Threatened and Endangered (T&E) Species – 14.4% of the 1999 identified park populations of federal T&E species with critical habitat on park lands or requiring NPS recovery actions have improved status, and an additional 20.5% have stable populations.	T&E species occur at five parks and are monitored by parks and other entities. The NPGN I&M Program will supplement this monitoring by tracking general landscape habitat conditions and stressors affecting T&E and other species.
Ia3. Air Quality – Air quality in 70% of reporting park areas has remained stable or improved.	Monitoring will supplement existing efforts to track selected air quality characteristics so parks can assess whether they are meeting this goal.
Ia4. Water Quality – 75% of 288 parks have unimpaired water quality.	Several parks have impaired water bodies (Table 1-5). The I&M Program will track water quality in streams and rivers to help assess success in meeting this goal.
Ib1. National Resource Inventories – Acquire or develop 87% of the 2,527 outstanding data sets identified in 1999 of basic natural resource inventories for all parks.	The I&M Program conducted baseline biological inventories for 10 park units. In 2006, the Network completed certification of species lists for vertebrates and vascular plants in all 13 parks.
Ib3. Vital Signs – 80% of 270 parks with significant natural resources have identified Vital Signs for natural resource monitoring.	The I&M Program helped all NGPN parks meet this goal in 2005.
Ib5. Aquatic Resources – NPS will complete an assessment of aquatic resource conditions in 265 parks.	All NGPN parks completed aquatic resource condition assessments. The I&M Program will monitor these resources for continued assessment.

The Use of Monitoring for Informing Park Resource Management

Monitoring is a critical component of adaptive management (Holling 1978) that provides continual feed back into the decision-making process. Long-term monitoring is one part of a multifaceted, hopefully integrated, natural resource management program. Park managers use additional methods (e.g., inventories, effectiveness monitoring, and scientific research to address major uncertainties) to assess resource conditions, trends, and management effects. Long-term monitoring complements other methods by providing data collected consistently over a period of decades. In contrast, research and other studies usually are implemented over short time periods (1–5 years) and often provide only a snapshot of current resource conditions. A long-term monitoring program can estimate conditions and trends in park resources and provide an early warning to managers that resources are being degraded and require action before the decline becomes severe or irreversible.

By integrating well-designed, multidisciplinary monitoring studies with other data collection efforts, NGPN ecologists can greatly increase their understanding of driving mechanisms and the likely effectiveness of alternative management strategies. By working with inventories, effectiveness monitoring, field research, and modeling, a clearer picture develops of the condition of park natural resources, the structure of park ecosystems, and the likely response of these ecosystems to changes in natural and anthropogenic influences.

The Natural and Cultural Context for Monitoring in the NGPN

Climate and Air Quality

The Northern Great Plains has a continental climate, with hot summers and cold winters (Figure 1-2). Snow pack is usually light and temporary except at parks in North Dakota and the central Black Hills. Most annual precipitation usually falls during the growing season; however, high variability and extremes are "normal" for the region at all temporal scales (Wilken 1988). For example, during Chinook wind events, Rapid City, South Dakota, has experienced temperature changes of nearly 50 °F within a few minutes and of 64 °F within 2 hours (Froiland 1990). Severe winters with long periods of snow cover occur periodically. The Great Plains regularly experiences multi-year droughts on a cycle that has ranged from 10–20 years over the past few centuries. Precipitation often shows large local differences that may persist for months or years.

Northern Great Plains temperatures have risen more than 2 °F in the past century (National Assessment Synthesis Team 2000). Current models predict a continued temperature rise of 5–12 °F and increasing precipitation during this century. Different climate models vary in predicting whether increased precipitation will balance increased evapotranspiration, or whether droughts will increase in occurrence (National Assessment Synthesis Team 2000). In either case, climate change could have dramatic impacts on ecosystems of the Northern Great Plains. For example, moderate changes could shift the dynamic interactions of C3 versus C4 grasses and of woodlands versus grasslands. Species in the region's highly fragmented habitats may have difficulty shifting their ranges as conditions change (Collins and Glenn 1995; Clark et al. 2002).

The Great Plains is renowned for its clean air and "big sky." Badlands, Theodore Roosevelt, and Wind Cave NPs have Class I air quality designations under the Clean Air Act. The risk of ozone impacts to vegetation in the region has been minor (Kohut 2004), yet some airborne pollutants such as nitrate, sulfate, and ammonium have increased (Pohlman and Maniero 2005). Park managers are concerned about potential further increases in these pollutants, ozone, and mercury due to continued oil and gas development in Wyoming, Montana, and western North Dakota. The sensitivity of NGPN ecosystems to current levels of these stressors and to plausible increases in ozone or nitrogen deposition is unclear.

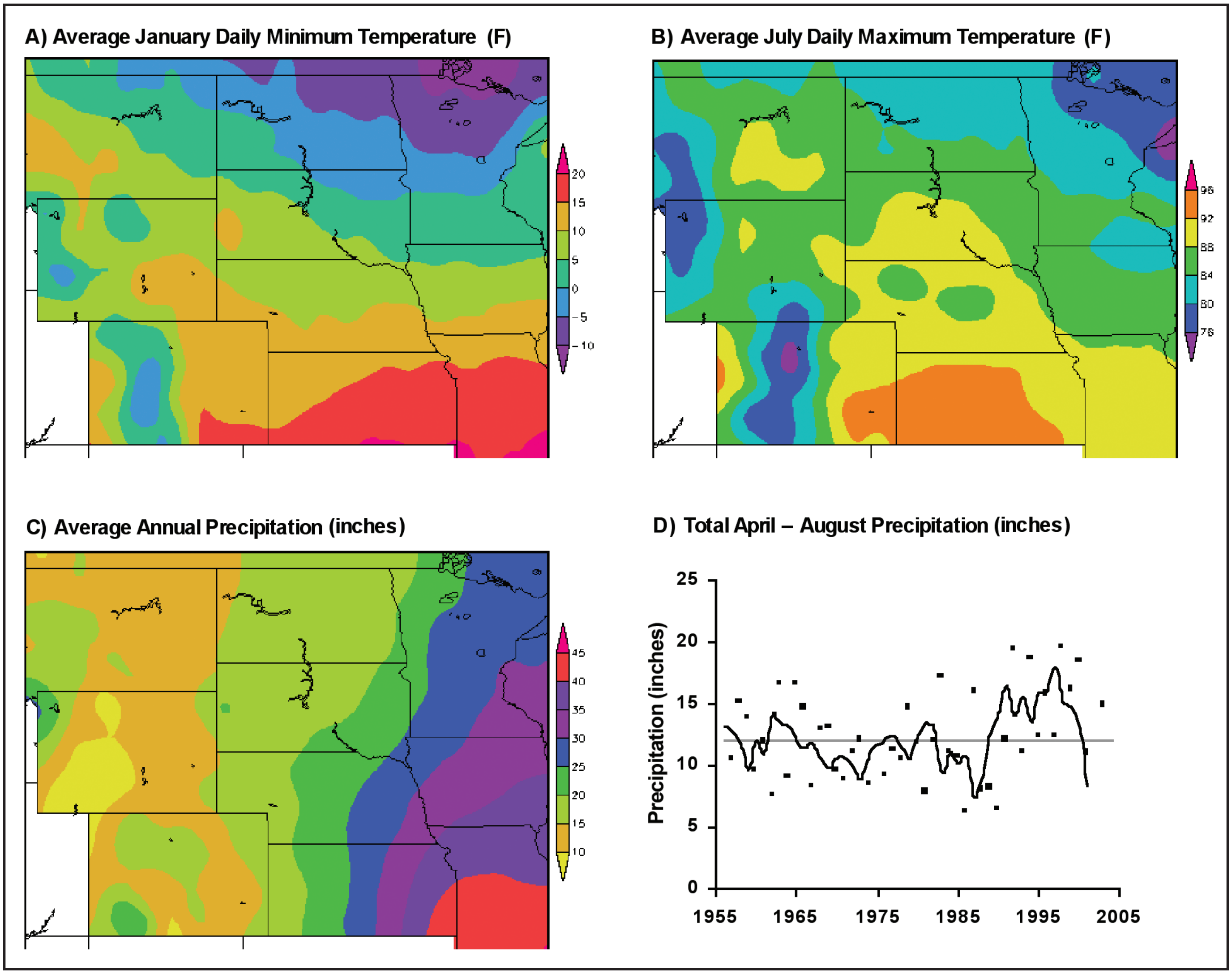


Figure 1-2. Climatic summaries for the NGPN.

A–C: Average temperature and precipitation for the U.S. Northern Great Plains and adjacent regions, 1961–1990. D: Total growing-season precipitation (squares) and smoothed trend (black line; 3-year moving average), 1956–2005, near Badlands NP (Interior, South Dakota). Years with more than two missing daily totals in one or more months are omitted (1975 and 2002). Gray line is the average for this period. Figures A–C and data for D from High Plains Regional Climate Center, University of Nebraska, Lincoln (HPRCC 2007).

Geology and Soils

Most of the NGPN is unglaciated, except at the eastern edge of the Network and in west-central North Dakota (mostly north of the Missouri River; KellerLynn 2007). Across the NGPN, geologic uplift and water and wind erosion have been the dominant processes shaping landforms, producing unique geologic features that initiated the establishment of several Network parks (e.g., Badlands NP, Wind Cave NP, Jewel Cave NM, Devils Tower NM, and Scotts Bluff NM). Deposition of sediment from the Rocky Mountains and Black Hills, uplift, and subsequent river and rainfall erosion created the dramatic topographic features of Badlands and Theodore Roosevelt NPs; smaller badlands are present at Scotts Bluff NM. The Niobrara NSR at the northern edge of the Nebraska Sandhills is a vast vegetated dune complex composed of fine windblown material deposited during glacial periods (Johnsgard 2001). Mount Rushmore is in the granitic core of the Black Hills, which began uplifting ~62 million years ago (Carter et al. 2002). Encircling the granitic core is a limestone formation, known as the Pahasapa Limestone, filled with caves, including Jewel Cave and Wind Cave, which currently are the second and fourth longest caves in the world, respectively. These caves formed as runoff from the granitic core of the Black Hills intersected the limestone and disappeared underground, where the limestone was dissolved as water from multiple sources mixed. The surface and the caves are integrally connected by shared hydrologic and climatologic systems. Water continues to flow into the limestone, recharging the Madison Aquifer.

Soils of the Great Plains generally are low in available nitrogen and have low moisture content for much of the year (Seastedt 1995), yet a large portion of prairie life occurs in the soil layer. For example, roughly 85% of a prairie's vegetative biomass can be below ground (Sims and Singh 1971). Common grasses of the western NGPN may be 0.5–2.5 feet tall but have roots extending 4–7 feet below the surface (Weaver 1968:17). Prairie dogs and pocket gophers spend much of their lives below the surface and have dramatic effects on soil structure. Fire and grazing can cause rapid pulses of soil transport. The soils, especially in the western portion of the Great Plains and in the Nebraska Sandhills, are susceptible to erosion once the protective vegetative layer is removed. In some portions of the Great Plains, recent models suggest that climate change may have significant effects on soil carbon levels; however, little or no change in soil carbon is expected in most of the NGPN except in the eastern portion of the Network, where soil carbon could decline by 15% during the 21st century under expected levels of climate change (Ojima and Lackett 2002).

Cultural Environment

Humans likely have occupied the Northern Great Plains for the last 12,000 years (Wedel 1983). By around 1770 the Crow, Kiowa, and Kiowa-Apache were displaced from the Black Hills region by Lakota, Arapaho, and Cheyenne groups moving in from the east and north. Mandan, Hidatsa and Arikara occupied the North Dakota area (Locay 1983). Euro-American settlement led to violent conflict and resettlement of Native Americans onto reservations. Most of western South Dakota, including the Black Hills, was set aside for the Lakota under the 1868 Treaty of Fort Laramie. This treaty was ignored after Custer's expedition confirmed discovery of gold in the Black Hills during the 1870s.

Several NGPN parks are in areas of high importance to Native Americans. Sites at Knife River Indian Villages NHS include individual earth lodge villages occupied continuously from ~1600–1850, and there is evidence of human activity for the last 11,500 years (Ahler et al. 1991). Wind Cave NP and Devils Tower NM contain sacred sites; Native Americans continue to visit the base of Devils Tower for quiet prayer and to use areas in Wind Cave NP for Sun Dances. The southern (Stronghold) unit of Badlands NP—approximately 50% of the park—is within the Pine Ridge Reservation and is co-managed by NPS and Lakota Sioux Nation. Some tribal groups want complete control of this unit to revert back to the Lakota. All

Black Hills parks are on contested lands, and although a 1980 U.S. Supreme Court decision recognized the treaty claim of the Lakota to lands in the Black Hills, a proposed cash settlement has not been accepted (Pommersheim 1988).

Many Network parks were important sites during the colonization of the region by Euro-Americans, including the Missouri River corridor traveled by Lewis and Clark, Fort Laramie and Fort Union Trading Post NHSs, and the Scotts Bluff area (Lavender 1983; Mattes 1992; Barbour 2001). Since this colonization, the Great Plains has remained a sparsely populated region with a strong agrarian culture. Unlike most of the U.S., the rural human population in the region has been declining in recent decades (Popper and Popper 1987; Licht 1997; Perry and Mackun 2001:4). Nevertheless, ranching remains a dominant industry in the western portion of the region, while farming dominates in the eastern portion. Although Network parks generally occur in areas poorly suited to cultivation, some parks contain tracts of formerly cultivated land. Portions of some park units and adjacent national grasslands were acquired to stop soil erosion and to bail out failing farms during the 1930s Dust Bowl.

The NGPN supports two designated wilderness areas. The Badlands Wilderness Area in the Sage Creek Basin of Badlands NP is ~64,250 acres, and wilderness areas in the north and south units of Theodore Roosevelt NP total ~29,929 acres. For large portions of their boundaries, Badlands, Theodore Roosevelt, and Wind Cave NPs, Jewel Cave NM, and Mount Rushmore NMEM are adjacent to national grasslands or national forests administered by the U.S. Forest Service; Wind Cave NP also shares part of its boundary with Custer State Park. Other NGPN parks are surrounded mostly by private agricultural lands. Scotts Bluff NM, Knife River Indian Villages NHS, and Theodore Roosevelt NP border small towns. Tourism continues to be a major part of the region's economy, especially for the Black Hills and for smaller "gateway" communities near national park units. Urban centers are comparatively small and widely spaced (Figure 1-3), although many parks are concerned about adjacent residential and hobby farm development.

Mineral and energy development are major industries in western North Dakota and eastern Wyoming. Coal mining and coal-fired power plants are common in west-central North Dakota and portions of Montana and Wyoming. Theodore Roosevelt NP and Knife River Indian Villages NHS have energy extraction sites or power plants within 10 miles of their boundaries. The Dakotas, Nebraska, Montana, and Wyoming currently have 30 active coal-fired plants generating an average >1.9 million megawatt-hrs per plant of net electricity annually (~5% of U.S. coal-fired power generation; NETL 2007*a*). Moreover, at least 23 new coal-powered plants are proposed for these states (NETL 2007*b*). States in the Northern Great Plains have among the highest wind energy potentials in the U.S. (Elliott and Schwartz 1999). Planned wind farm developments would increase current wind energy production in North Dakota and South Dakota 2- to 3-fold over current production (American Wind Energy Association 2006). Energy is also produced and dispersed from hydroelectric dams when flows are sufficient, primarily on the Missouri River. Such external influences present major challenges for managers seeking to maintain or improve the condition of park resources. Comprehensive discussions of Northern Great Plains land use, economics, demographics, and culture can be found in Webb (1931), Popper and Popper (1987), Callenbach (1996), Licht (1997), and Wishart (2004).

Vegetation and Natural Disturbances

The NGPN parks are located in mixed-grass prairie, mixed-grass/tallgrass and mixed-grass/shortgrass transitions, and Black Hills ponderosa pine ecoregions (Küchler 1985; Omernik 1987; Bailey 1995). Grasslands dominate ~40% of the land area of the 13 NGPN parks (Table 1-3; USGS 2005). Dominant grasses include western wheatgrass, green needlegrass, needleandthread, blue grama, buffalograss, and big and little bluestem (see Appendix A for scientific names). Woody draws and patches of green ash, juniper, and shrubs make up a small portion of the grassland landscape but are of high ecological importance (Figure 1-4). Woodlands of cottonwood, green ash, and American elm occur along the larger streams and rivers. Ponderosa pine dominates Black Hills forests. The Black Hills foothills (portions of Wind Cave NP and Devils Tower NM) are a heterogeneous and dynamic mix of grasslands, savanna, and closed-canopy pine forests.

Great Plains vegetation communities are shaped by fire, grazing, soil type, landform (e.g., badlands and draws), flooding, and climate, especially the amount, season, and variability of precipitation (Bachelet et al. 2000; Sims and Risser 2000). Climatic variability in the NGPN, which includes multi-decade periods drier or wetter than the century-scale average, has large impacts on vegetation (Albertson and Weaver 1945; Clark et al. 2002).

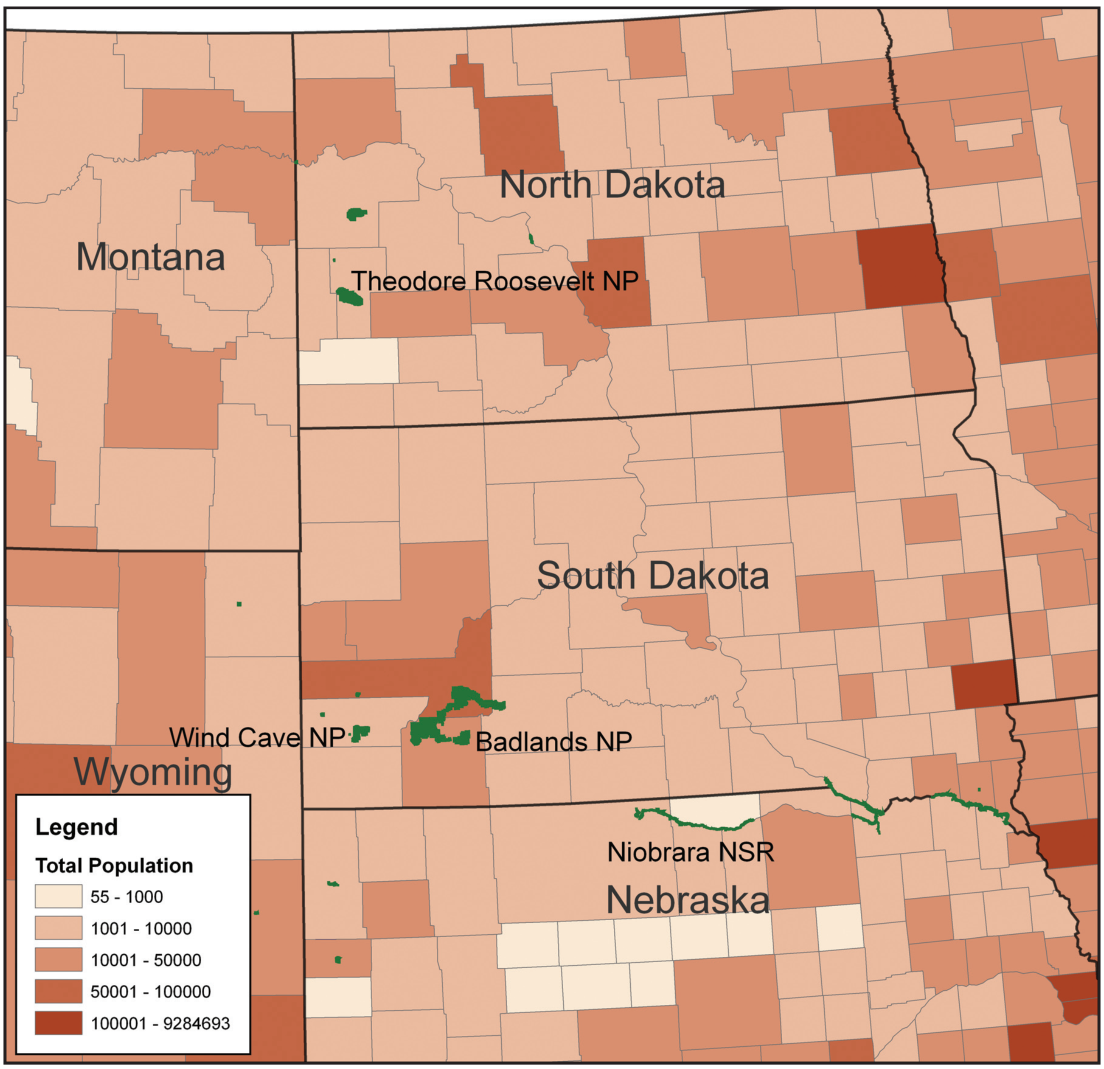


Figure 1-3. Population by county (year 2000) in the U.S. Northern Great Plains. Source: U.S. Census Bureau (2007). Selected NGPN parks are labeled for reference.

For example, Weaver (1943) reported that the mixed-grass prairie biome shifted east a hundred miles during the Dust Bowl of the 1930s. Even under average conditions, soil moisture often is low enough to stress native plants of this region.

Historically, frequent fires and grazing were primary disturbances of NGPN terrestrial systems, as in grasslands worldwide (e.g., Anderson 1982; Milchunas et al. 1988). Annual flooding and shifting of river channels drove vegetation patterns in riparian areas (Appendix B). Grazing is still a dominant ecological process in the region; however, in landscapes adjacent to parks, heterogeneous grazing by native species has been replaced by homogeneous grazing by livestock (Hart and Hart 1997). The region's largest native herbivores, bison and elk, are absent from most parks. In the three parks supporting bison (Badlands, Theodore Roosevelt, and Wind Cave NPs), confinement of herds within park boundaries produces grazing patterns different from the presettlement disturbance pattern. Parks with rivers suffer from lack of tree recruitment and degradation of riparian forests resulting from flood control, disease, and exotic plants.

Natural fires have been suppressed for decades in the Northern Great Plains, including in NGPN parks. In the Black Hills, absence of fire during most of the 20th century led to greatly increased tree densities in formerly open forests where more frequent, lower severity, fires were historically characteristic (Brown and Cook 2006). These dense forests are at high risk of severe, stand-replacing fires (Brown et al. 2008) as well as an increased risk of mountain pine beetle epidemics. Reducing the likelihood of such events is a high priority for maintaining old-growth pine forests at Mount Rushmore NMEM (Symstad and Bynum 2007). Lack of fire also allowed expansion of conifer forests and woodlands at the expense of grasslands in the Black Hills (Brown and Sieg 1999). In addition, the absence of fire allows encroachment of eastern red-cedar into grasslands in portions of Missouri NRR and Niobrara NSR. Prescribed burning and fuels treatments by the Northern Great Plains Fire Management Office and park staff attempt to mitigate the effects of the absence of natural fires, but the extent of these fires and the conditions under which they occur are different from the regimes that shaped the ecosystems.

Invasion of exotics is a major natural resource problem in all Network parks (Larson et al. 2001). Smooth brome dominates the understory of many riparian areas, and annual brome grasses are common in many upland sites. Kentucky bluegrass is a naturalized and sometimes dominant component in some parks. Infestations of Canada thistle, musk thistle, leafy spurge, and houndstongue are priorities for treatment by the Northern Great Plains Exotic Plant Management Team (EPMT) at most Network parks (NPS 2005*a*). Woody riparian invaders of high concern include Russian olive, which is present in many riparian zones of the region, and tamarisk, which is present but not established in Network parks (NPS 2007*a*).

Exotic invasions have produced large changes in plant species composition of many NGPN communities and have reduced species richness in many sites (e.g., Butler and Cogan 2004). Although fire, grazing, and other disturbances shaped the natural vegetation of the Network, currently exotics often dominate post-disturbance communities. In some cases (e.g., where infestations of leafy spurge or smooth brome occur), post-disturbance recovery of native vegetation may not occur without intensive management. In other regions of western North America, invasive species have dramatically altered ecological processes such as disturbance regimes, water transport, and nutrient cycling (e.g., Stewart and Hull 1949; Stromberg et al. 2007). There is high concern that invasive species may reshape NGPN ecosystems to a similar degree (Christian and Wilson 1999), particularly under projected climate changes (National Assessment Synthesis Team 2000).

Aquatic Resources

Two NGPN units (Missouri NRR and Niobrara NSR) were established specifically because of their aquatic resources. In these parks, the Missouri River and Niobrara River are Outstanding Natural Resource Waters as defined by the Clean Water Act of 1977. Although surface water makes up a small area of other Network units (Tables 1-3 and 1-4), aquatic systems play a major ecological role throughout this semi-arid region. In many cases, dams, irrigation and municipal withdrawals, groundwater depletions, and other land uses have impacted hydrology, riparian flora and fauna, streambed structure and function, and water quality (Longo and Yoskowitz 2002). Channelization and changes in sediment transfer also have altered the Missouri River (National Research Council 2002). Reduction of flooding has halted cottonwood regeneration in most of the region. Although flooding has been reduced, dams, irrigation, and stock ponds have increased availability of surface water in many areas. Water quality has been affected by herbicides and other pollutants. Several parks have impaired waters according to the Clean Water Act 303(d) (Table 1-5); however, some aquatic impacts are counter to conventional views of water quality. For example, Missouri River water has lower sediment loads and turbidity now than under natural conditions, making these "cleaner" waters less healthy from the perspective of ecological integrity and native species (Natural Research Council 1995). For example, juvenile pallid sturgeon thrive best in turbid waters where predators are less likely to find them (Hesse and Sheets 1993; USFWS 1993).

Subsurface water quantity and quality is also a concern in some Network parks due to groundwater depletion from neighboring lands (primarily for irrigation), groundwater pollution from pesticides (primarily herbicides), and hydrocarbons (e.g., pollution from parking lots and roads at Jewel Cave NM and Wind Cave NP). Groundwater depletion is of regional concern for both Great Plains ecology and human society (Kromm and White 1992). In the NGPN, groundwater depletion is of highest concern in parks of Nebraska and the Black Hills. For example, Luckey et al. (1988) reported groundwater declines of 50–100 feet in the vicinity of Network parks in western Nebraska. The effects of climate change on overall water quantity and timing of water-level fluctuations is another key concern for the region (National Ecological Synthesis Team 2000). For a thorough review of Great Plains water resources and management issues see Longo and Yoskowitz (2002).

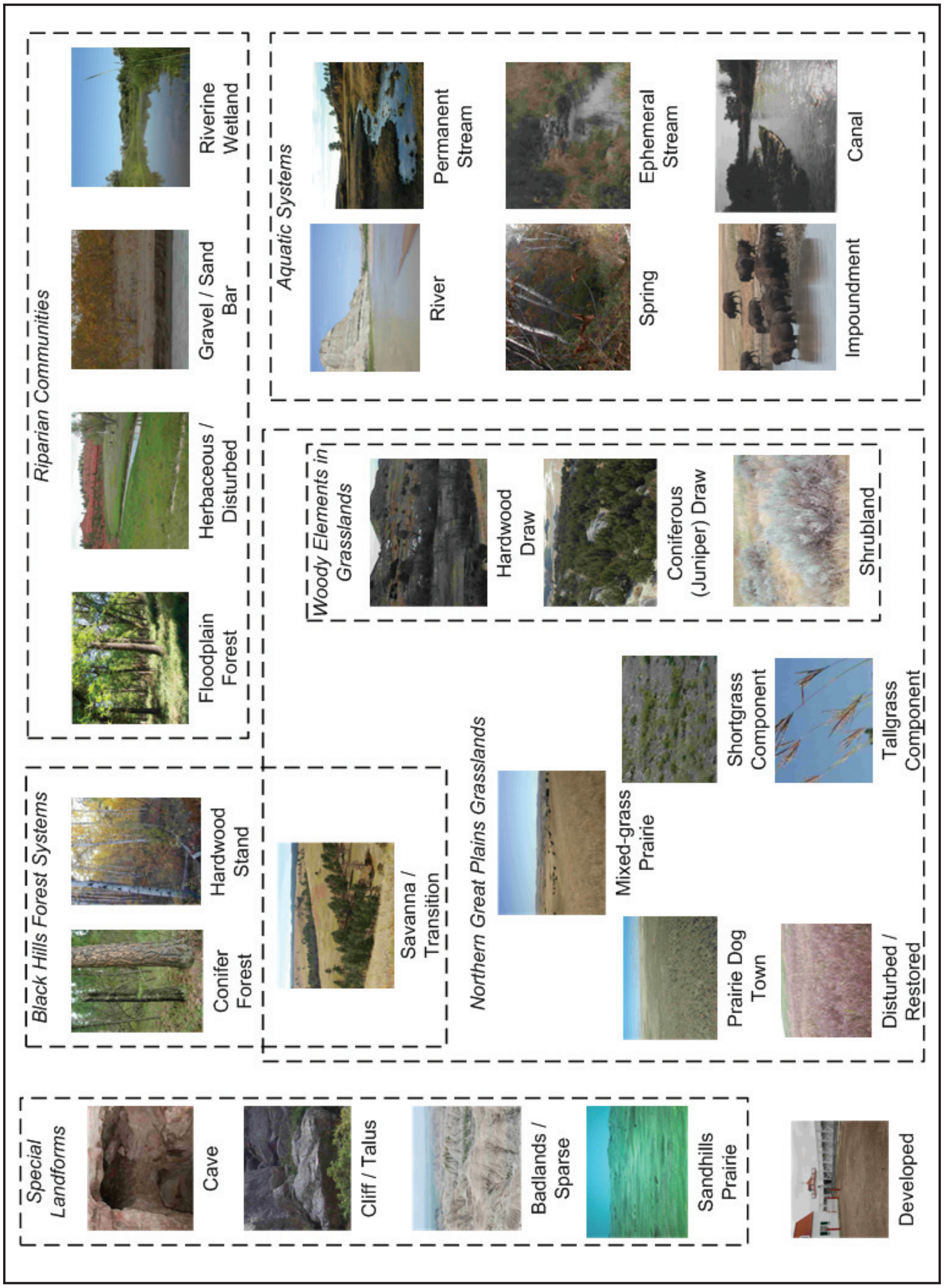


Figure 1-4. Ecosystems of the NGPN.

Table 1-3. Area (acres and percentage of park) for selected land cover types of parks in the NGPN.

Park[a]	Forest	Shrubland	Native Grassland	Wetland/ Moist Soil	Barren	Surface Water	Disturbed Sites	Administrative Areas
Agate Fossil Beds NM	20 (1%)	24 (1%)	2,320 (75%)	234 (8%)	0 (0%)	1 (0%)	334 (11%)	150 (5%)
Badlands NP	3,590 (1%)	6,916 (3%)	111,944 (46%)	592 (0%)	111,999 (46%)	180 (0%)	6,800 (3%)	549 (0%)
Devils Tower NM	777 (58%)	13 (1%)	411 (30%)	0 (0%)	60 (4%)	9 (1%)	70 (5%)	3 (0%)
Fort Laramie NHS	104 (12%)	11 (1%)	348 (41%)	3 (0%)	63 (7%)	22 (3%)	243 (28%)	63 (7%)
Fort Union Trading Post NHS	50 (11%)	28 (6%)	126 (28%)	0 (0%)	0 (0%)	5 (1%)	203 (46%)	29 (7%)
Jewel Cave NM	1,215 (95%)	46 (4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (0%)	11 (1%)
Knife R. Indian Villages NHS	377 (22%)	78 (5%)	337 (20%)	3 (0%)	12 (1%)	112 (7%)	757 (44%)	32 (2%)
Missouri NRR	8,647 (13%)	0 (0%)	4,786 (7%)	10,326 (15%)	12 (0%)	31,104 (45%)	13,807 (20%)	0 (0%)
Mount Rushmore NMEM	1,112 (86%)	0 (0%)	0 (0%)	2 (0%)	113 (9%)	0 (0%)	0 (0%)	67 (5%)
Niobrara NSR	7,521 (26%)	0 (0%)	11,776 (41%)	1,235 (4%)	4 (0%)	5,836 (20%)	2,493 (9%)	0 (0%)
Scotts Bluff NM	230 (7%)	257 (8%)	1,544 (48%)	7 (0%)	687 (21%)	8 (0%)	472 (15%)	0 (0%)
Theodore Roosevelt NP	14,679 (21%)	9,553 (14%)	27,812 (40%)	28 (0%)	14,421 (21%)	651 (1%)	2,274 (3%)	551 (1%)
Wind Cave NP	8,170 (29%)	2,142 (8%)	17,049 (60%)	25 (0%)	276 (1%)	4 (0%)	394 (1%)	171 (1%)
Total	46,492 (10%)	19,068 (4%)	178,453 (40%)	12,455 (3%)	127,647 (28%)	37,932 (8%)	27,849 (6%)	1,626 (<1%)

[a]Data for all parks from the U.S. Geological Survey (USGS) Vegetation Mapping Program, except for Missouri NRR and Niobrara NSR, which came from the National Land Cover Dataset. Acreages may not sum to actual acres within park boundaries due to methods used. Acreages are not directly comparable between park units due to differences in photo-interpreters.

Table 1-4. Aquatic resources in NGPN parks. Values are miles of streams, rivers, and canals, and acres of lakes, reservoirs, and impoundments.

Park	Perennial Streams/ Rivers in Park[a]	Perennial Streams/ Rivers Bordering Park	Intermittent Streams	Canals	Lakes, Reservoirs, and Impoundments[b]	Wetlands/ Springs
Agate Fossil Beds NM	8.5	0	4.0	0.8	0	P[c]
Badlands NP	3.8	0	715.8	0	115.3	P
Devils Tower NM	0.9	1.3	1.1	0	0	P
Fort Laramie NHS	2.5	1.4	0.6	0.1	0	P
Fort Union Trading Post NHS	0	1.2	0.1	0	0	P
Jewel Cave NM	0	0	4.1	0	0	P
Knife R. Indian Villages NHS	4.4	0.1	1.0	0	0	P
Missouri NRR	139.3	n/a	12.5	2.7	329.5	P
Mount Rushmore NMEM	<0.1	0	P	0	0	P
Niobrara NSR	91.7	n/a	9.9	0	21.6	P
Scotts Bluff NM	0	1.5	P	P	0	P
Theodore Roosevelt NP	21.2	7.4	268.8	0	5.3	P
Wind Cave NP	7.5	0	63.5	0	1.2	P
Total	280	13	1,081	3.6	473	

[a]Water data from USGS 1:100,000 scale National Hydrography.

[b]Lakes and reservoirs in Badlands, Theodore Roosevelt, and Wind Cave NPs consist solely of small impoundments created for livestock or wildlife.

[c]Present but values not available.

Table 1-5. Baseline historical data and stressors of water resources of the NGPN.

Park	Data[a]	Water Quality Issues and Potential Stressors of Water Resources	303(d) Listed Waters[b]	303(d) Impairments
Agate Fossil Beds NM	1952–1993	Based on limited historical data, water quality appears good (Martin 2005), but park managers are concerned about effects of upstream pesticide use, fertilizers, and ranching inputs. Upstream irrigation withdrawals affect the Niobrara River. Exotic brown trout were stocked until the late 1990s.		
Badlands NP	1962–1996	Some historical samples from park streams reported high turbidity and total coliform counts as well as elevated concentrations of sulfate, dissolved nitrite, copper, and lead. The CCC Spring originates on private lands that receive high loads of pesticides and fertilizers. There is concern about the ecological impacts of the artificial stock ponds maintained for bison watering.		
Devils Tower NM	1967–1992	Water Resources Division (WRD) assessments have found some historical values above state standards for turbidity, fecal coliform, sulfate, and suspended cadmium values. Currently, the Belle Fourche River may be affected by inputs from private rangeland and herbicide use within and outside the park. An upstream dam altered the hydrograph.	Belle Fourche R. between Arch Cr. and Hulett	pathogens (*E. coli*)
Fort Laramie NHS	1901–1988	From 1973 to 1980, samples indicated a few water quality criterion violations for turbidity, coliform counts, and metals in the Laramie and North Platte rivers. Dams affect the Laramie and North Platte rivers. An irrigation canal south of the park affects park resources through seepage and other hydrologic effects.		
Fort Union Trading Post NHS	1974–1975	The park straddles the Missouri River but owns property only above the high-water mark. Few data are available to assess water quality of the Missouri River near FOUS. The Ft. Peck dam upstream on the Missouri River altered the natural river hydrograph. Riverbank erosion jeopardizes cultural resources and the park land base.	Missouri R. from Poplar R. to ND	Flow alterations, thermal modifications

[a]Denotes historical data gathered in “Baseline Water Quality Inventory and Analysis Reports” by the WRD.

[b]Source: http://www1.nrintra.nps.gov/wrd/DUI/index.cfm (NPS intranet); updated 13 June 2008.

Table 1-5. Baseline historical data and stressors of water resources of the NGPN (continued).

Park	Data[a]	Water Quality Issues and Potential Stressors of Water Resources	303(d) Listed Waters[b]	303(d) Impairments
Jewel Cave NM	1963–1998	Cave resources and springs could be impacted if groundwater quality is altered or if leaks and overflows from the sewage system occur. Groundwater contamination in portions of the Black Hills may be caused by private septic systems.		
Knife R. Indian Villages NHS	1975–1991	The Knife River may be affected by pesticide use, cultivation, and livestock operations upstream. Natural bank erosion threatens an archeological site. The Missouri River borders the park but mostly is outside of the park boundary.	Knife R. (Antelope Cr. confluence to Missouri R. confluence)	Pathogens (total coliform)
Missouri NRR	1948–1997	Effects of dams on the Missouri River are the most significant natural resource issues. Sandbar habitats have been lost because the dams block sediment transport and reduce scouring events. The loss of periodic inundation of the bottomlands may be affecting cottonwood regeneration and nutrient cycling. Bank erosion continues to be a concern, but bank stabilization is also a resource stressor. Degradation and reduction in backwater habitats may be affecting amphibians and other wildlife. River management is complex due to the numerous agencies involved, with the U.S. Army Corps of Engineers having primary management authority for the river.		
Mount Rushmore NMEM	1957–1998	Historically, WRD noted some exceedences for dissolved oxygen, pH, turbidity, and fecal coliform. Current concerns include surface water runoff from the parking lot and roads, and impacts from developed infrastructure.		
Niobrara NSR	1948–1993	Historical data reported high fecal coliform values. Current pollution concerns include nonpoint inputs from cattle, the potential for additional point sources as more feedlots are established, and effects of the high number of canoeists. Dams below and at the upper end of the Niobrara NSR reach have altered hydrology and present barriers to fish movement. An increase in center-pivot irrigation in the uplands may affect hydrology.	Minnechaduza Cr. (segment extends from Dry Cr. confluence)	pathogens, thermal modifications

Table 1-5. Baseline historical data and stressors of water resources of the NGPN (continued).

Park	Data[a]	Water Quality Issues and Potential Stressors of Water Resources	303(d) Listed Waters[b]	303(d) Impairments
Scotts Bluff NM	1961–1988	The North Platte River is affected by upstream dams, irrigation withdrawals, and inputs of pesticides, sediment, and nutrients. Water quality and quantity at Scotts Spring is a concern to park staff.	North Platte R.	pesticides, PCBs, thermal modifications
Theodore Roosevelt NP	1949–1996	Water quality data collected from 1968 to 1995 indicated that a large number of parameters exceeded screening criteria. The Little Missouri River is impaired in all three park units. Adjacent rangeland may affect water quality. Irrigation withdrawals occur at a nearby golf course.	Little Missouri R. (from Beaver Cr. confluence downstream to Hwy. 85)	Pathogens (fecal coliforms)
Wind Cave NP	1963–1998	Historically, samples of dissolved oxygen, pH, fecal coliforms and some metals exceeded screening criteria. Developments and land-use practices may have reduced regional surface water flows. Fish kills have been observed in Highland Creek. Groundwater contamination in portions of the Black Hills may be caused by private septic systems.		

Fauna

Like grasslands worldwide, the Northern Great Plains historically supported large populations of gregarious species that were nomadic or migratory (Knopf and Samson 1997). Species such as bison, prairie dogs, and migrating waterfowl occurred in almost unfathomable numbers. Large numbers of bison likely grazed an area and then moved on, creating a mosaic of successional stages across the landscape (Hart and Hart 1997). Wolves and Native Americans preyed heavily on bison; resulting carrion probably was critical in supporting decomposers and scavengers such as the swift fox and raven (Freilich et al. 2003).

Wolves have been extirpated in the region and bison are now absent from most parks. Areas of the Great Plains have lost a greater number of native carnivores (e.g., wolves, black and grizzly bears) and ungulates than any other North American biome (Laliberte and Ripple 2004). However, large parks of the NGPN still support many ecologically dominant native species of the region. Wind Cave, Badlands, and Theodore Roosevelt NPs support large bison herds; these parks, along with Scotts Bluff and Devils Tower NMs, also support prairie dogs (Table 1-6). In addition to their role as grazers, bison are agents of physical disturbance (e.g., by creating wallows) and nutrient cycling. Through their burrowing activities, herbivory, and role as a prey base, prairie dogs have major influences on grassland soil structure, nutrient cycling, and community composition (Miller et al. 2000; Kotliar et al. 2006).

Although black-footed ferrets were extirpated in the Network, Badlands NP currently supports a reintroduced population of 10–30 black-footed ferrets and borders a larger reintroduced, established population at Conata Basin. Wind Cave NP began reintroducing this federally endangered species in 2007. Other federally listed species in Network parks include least tern and piping plover (~247 and 170 pairs, respectively, at Missouri NRR; 13 and 9 pairs at Niobrara NSR); whooping crane (a rare migrant at Niobrara NSR and the Badlands NP area); pallid sturgeon (present at Missouri NRR and Knife River Indian Villages NHS); and two mussels, scaleshell and Higgins eye (documented by a single shell each at Missouri NRR, but not detected in recent surveys). Piping plovers are threatened, while other species listed are endangered. Missouri NRR also supports ~14 pairs of the recently delisted bald eagle (population estimates are from park staff for 2004–2005).

Local residents highly value large ungulates and other wildlife and fish supported by NGPN parks, but some people also view parks as undesired refuges or landscape sources for prairie dogs and elk. In the surrounding landscape, prairie dogs and other species are heavily controlled because of competition, perceived or real, with other land uses (Miller et al. 2007). Wind Cave and Theodore Roosevelt have considered use of hunting to manage elk populations; these parks and Badlands NP have frequent live culls of bison. Conversely, at Mount Rushmore NMEM, visitors greatly enjoy viewing mountain goats, a species not native to the region. Because of strong public feelings about prairie dogs, elk, and other charismatic species, wildlife management within Network parks can be contentious.

Table 1-6. Occurrence of vertebrates and plant species of concern in NGPN parks.

	Confirmed Native Vertebrates[a]					Native Large Mammals and Prairie Dogs[b]							Plants of Concern[c]	
Park	Amphibians	Reptiles	Fishes	Birds	Mammals	Bison	Elk	Bighorn Sheep	Mule (M) / White-tailed (W) Deer	Pronghorn	Mountain Lion	Prairie Dog (acres)	Globally Vulnerable Plants	Globally Vulnerable Communities
Agate Fossil Beds NM	4	11	0	105	34				M, W	U			2	4
Badlands NP	5	6	13	196	36	870		90	M, W	120	U	6,284	2	12
Devils Tower NM	6	6	9	113	40		U		M, W	U	U	40		9
Fort Laramie NHS	3	6	16	94	23				M, W	U				3
Fort Union Trading Post NHS	6	4	0	93	18				W					2
Jewel Cave NM	3	1	0	82	28		P		M, W		P			4
Knife R. Indian Villages NHS	4	3	8	137	28				M (U), W	U				4
Missouri NRR	9	17	55	231	38		U		M (U), W		U		n/a	n/a
Mount Rushmore NMEM	2	4	1	49	28			U	M, W		P			5
Niobrara NSR	9	19	21	218	41		P		M, W	U	U		n/a	n/a
Scotts Bluff NM	5	7	20	118	28				M, W	U		90	1	6
Theodore Roosevelt NP	6	9	21	151	34	610	750	20	M, W	P	P	1,230	1	11
Wind Cave NP	6	9	5	208	50	400	825		M, W	60	P	2,000	1	10

[a]Number of species certified as present (including migrants) in NPSpecies; includes native and potentially native (i.e., unknown nativity) species.

[b]Large-mammal numbers are approximate population sizes with unspecified precision/bias. Population estimates are from park staff and are generally from spring/summer of 2004 for birds and late summer to winter of 2004–2005 for large mammals. At WICA, elk use is seasonal with 400–425 in summer and 800–850 in winter. Deer population estimates are available only for BADL (270 M, 110 W) and Wind Cave (150 M, 50 W). Prairie dog numbers are acres occupied. P = species present on a regular basis but no estimate available; U = certified as present but irregular or non-breeding/incidental occurrence; n/a = not available.

[c]Globally vulnerable plants and communities are those ranked G3, G2, or G1 (from Symstad 2004).

Summary of Resource Concerns

Although NGPN parks support regional, national, and internationally unique resources, none of the parks is large enough to restore and maintain complete assemblages of native species or disturbance regimes on a scale comparable to that of pre-European settlement conditions. Managers must continue to address numerous threats to the condition of each park's natural resources. Literature reviews (Chapter 2) and discussions (Chapter 3) among Network managers, I&M staff, and external scientists indicated that the following natural resource issues are of highest concern:

- Changes in adjacent land uses, contributing to all concerns below
- Alteration of disturbance frequency and intensity (e.g., increased risk of high-severity fires in Black Hills forests; near-elimination of natural flooding on large rivers; absence of bison grazing in most parks), and amplification of disturbance effects because of the small size of most parks (e.g., effects of prairie dog grazing during droughts)
- Management and impacts of high populations of ungulates in the absence of predation
- Invasive species, particularly terrestrial and riparian plants
- Aquatic and riparian degradation (e.g., from upstream pollutants, changes in natural flow patterns due to dams, exotic species, and water removals)
- Increased air pollution that affects park resources (e.g., ozone damage to plants; effects of increased nitrogen inputs) and visitor experiences (e.g., vistas)
- Anthropogenic climate change
- Loss of native plant and animal species, and challenges in restoring native species
- Degradation of other special park resources and features, particularly caves, soundscapes, and night sky darkness. Both Jewel Cave and Wind Cave receive heavy tour use and are also vulnerable to water-borne pollutants, changes in groundwater infiltration amounts and aquifer levels, and altered microclimates caused by global climate change and human uses (e.g., tour lights, body heat, alteration of airflow due to passage enlargement)
- Effectiveness and unexpected effects of prescribed burning, herbicide spraying, species reintroductions, culling of large grazers, restoration, and other management actions

Overview of Current Monitoring In and Near NGPN Parks

Agate Fossil Beds and Scotts Bluff NM are both part of the Prairie Cluster Prototype program based at Wilson's Creek National Battlefield in Republic, Missouri. At these two Network parks the long-term monitoring plan will build on existing monitoring with well-defined sampling protocols for several Vital Signs. The program at Agate Fossil Beds NM has monitored aquatic macroinvertebrates on the Niobrara River since 1989, vegetation composition and structure since 1998, and grassland bird abundance since 2001. At Scotts Bluff NM, the density, and colony area of prairie dogs have been monitored since 1995, while vegetation has been monitored since 1997. In 2010, the NGPN will assume responsibility for monitoring of vegetation, water quality, and prairie dogs at these parks.

Other current multi-park monitoring focuses on weather and climate, air quality, and prescribed burning. Air quality monitoring in the NGPN includes stations operated by the NPS or state agencies for several national networks (Figure 1-5; Table 1-7; Pohlman and Maniero 2005). Only Class 1 air quality parks (Badlands, Wind Cave, and Theodore Roosevelt NPs) have long-term monitoring stations within their boundaries. Devils Tower NM, Knife River Indian Villages NHS, and parks in Nebraska are in the largest gaps in current regional station coverage. Most NGPN parks have daily weather observations or automated stations (Table 1-8; Davey et al. 2007).

To track effects of fire management programs, the Northern Great Plains Fire Ecology Program (FireEP) stationed at Wind Cave NP has monitored vegetation composition and structure before and after prescribed fires (up to 5 years after burning) since 1997. The NGPN I&M Program is working closely with ecologists of the FireEP to integrate vegetation monitoring across both programs. The Northern Great Plains EPMT stationed at Theodore Roosevelt NP does not conduct formal long-term or effectiveness monitoring, but maps and maintains a spatial database of areas surveyed and treated each year.

Within the parks, aquatic monitoring consists of a few park-specific efforts and separate efforts by other agencies rather than an integrated program (Table 1-9). The U.S. Geological Survey (USGS) monitors flow on most major streams and rivers in or near Network parks. Natural resource districts in western and central Nebraska monitor groundwater levels and quality; several Network parks have begun monitoring aquifer water levels through existing wells. Numerous other terrestrial monitoring projects target high-priority resources at individual parks, with longest-term data sets for abundance of bison and acreages of active prairie dog towns. Where federally listed vertebrates occur as residents in NGPN units, park staff or other agencies monitor populations at the park or regional level.

Region-wide trends can be examined from extensive weather and air quality monitoring in the Northern Great Plains. Similarly, the North American Breeding Bird Survey has extensive routes throughout the region (USGS 2007). However, the region has no long-term ecological monitoring sites comparable to Long Term Ecological Research (LTER) sites of the tallgrass (Konza Prairie, Kansas) and shortgrass (Shortgrass Steppe, eastern Colorado) biomes. The Black Hills National Forest (NF) monitors regional-scale vegetation structure as part of the U.S. Forest Service (USFS) Forest Inventory and Analysis. The USFS Forest Health Management program aerially maps insect and disease damage and mortality throughout the Black Hills; they regularly map damage in NGPN Black Hills parks and have surveyed woodlands in other Network parks when funding permits. The Black Hills NF also conducts landscape-scale bird monitoring. State agencies focus on game species, in addition to water and air resources.

To maximize its efficiency the NGPN will take advantage of some of these current monitoring efforts (Chapters 3 and 5) that provide critical information for understanding the condition of park resources (e.g., data from USGS stream/river gages). Data relevant to Network monitoring may also come from other regions and from national-scale programs. The newly developed National Ecological Observatory Network plans to measure air quality, climate, carbon cycling, soil characteristics, and water quality at sites in eastern North Dakota and at the Shortgrass Steppe LTER site (NEON 2008). The NGPN borders the Heartlands, Southern Plains, Rocky Mountains, and Great Lakes I&M Networks, which have implemented large-scale Vital Signs monitoring programs. When possible, I&M Networks may integrate some data sets to allow analysis of broader regional trends. For example, the NGPN will measure plant species richness in a manner compatible with methods used by other I&M Networks that are monitoring plant composition in the Great Plains (Heartland and Southern Plains Networks) to allow integration of data.

Table 1-7. Air quality monitoring in NGPN Class 1 air quality parks. Year = start year for active stations.

Network	Measurements	BADL	THRO	WICA
Interagency Monitoring of Protected Visual Environments (IMPROVE)	Visibility and particulates	1988	1999	1999
National Atmospheric Deposition Program/National Trends Network (NADP/NTN)	Precipitation chemistry and wet deposition	1983[a]	2001	2002
Clean Air Status and Trends Network (CASTNET)	Dry acidic deposition		1998	2003
NPS Gaseous Pollutant Monitoring Program (GPMP)	Particulates/gaseous pollutants	2004	1998[b]	
Ozone monitoring[c]	Ozone	2003	1975	1995

[a]Cottonwood NADP/NTN site at Cottonwood, 20 km northeast of park.

[b]Particulates monitored since 2004.

[c]Monitored at CASTNET or GPMP network stations.

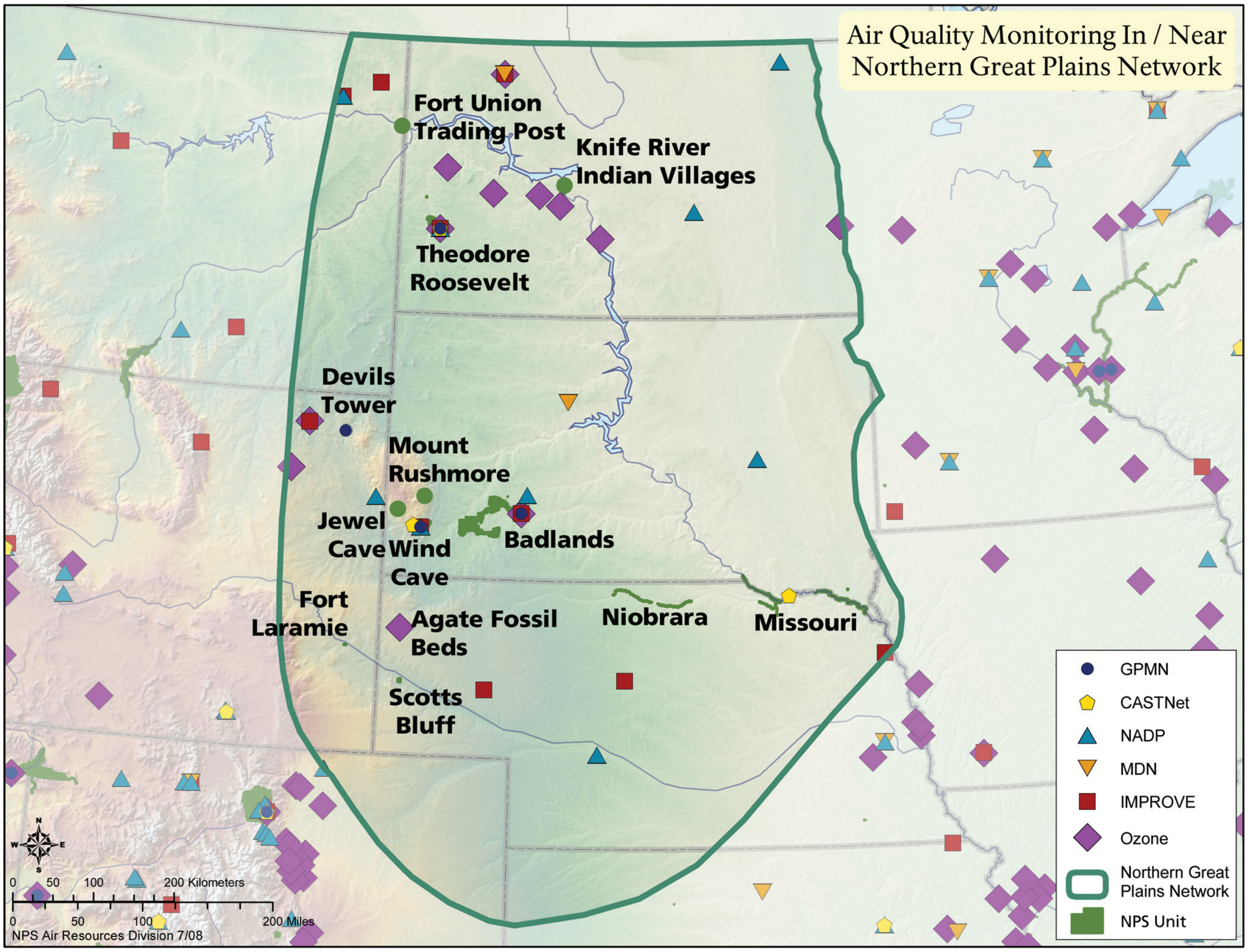


Figure 1-5. Air quality monitoring networks in the Northern Great Plains. See Table 9 for abbreviations; MDN = Mercury Deposition Network. Source: NPS (2008*a*).

Table 1-8. Current weather and climate monitoring in NGPN parks.

Includes stations within 1 km of park. Years are start dates; end dates are listed only for stations no longer active. Stations of poor reliability or with many gaps are omitted. See Davey et al. (2007) for a complete description.

Park	Daily Summary Data[a]	Hourly Data[b]
Agate Fossil Beds NM	Late 1960s	2003 (CRN); 1999 (RAWS)
Badlands NP	1955	2003 (GPMP; also GPMP from 1987–1992); 1999 (RAWS); 1998 (NADP, <1 km outside park)
Devils Tower NM	1959, 1999	1999 (RAWS)
Ft. Laramie NHS	1989	None
Ft. Union Trading Post NHS	Start unknown	None
Jewel Cave NM	None	2007 (AWDN)
Knife R. Indian Villages NHS	None	2008 (RAWS)
Missouri NRR	1939, 1989 (Lewis and Clark Lake)	None
Mount Rushmore NMEM	1962	2000 (RAWS)
Niobrara NSR	1886 (Valentine)	None
Scotts Bluff NM	1984–2001	2001 (RAWS)
Theodore Roosevelt NP (N)	1951	None; three stations no longer active
Theodore Roosevelt NP (S)	None	1998 (CASTNET), 2004 (CRN), 1998 (GPMP), 2001 (NADP)
Wind Cave NP	1990[c]	2003 (CASTNET), 2002 (NADP), 1996 (RAWS)

[a]All daily summaries are from NWS Cooperative Observer Program (COOP) stations except at SCBL, where records are from a station operated by park staff. COOP stations record max/min temperature, daily precipitation, daily snowfall, and snow depth.

[b]AWDN = Automated Weather Data Network; CASTNET = Clean Air Status and Trends Network; CRN = National Oceanic and Atmospheric Administration (NOAA) Climate Reference Network; GPMP = Gaseous Pollutant Monitoring Program; GPS-MET = NOAA Ground-based GPS Meteorology; NADP = National Atmospheric Deposition Program; RAWS = Remote Automated Weather Station Network; SAO = NWS Surface Airways Observation Network. Measurements include precipitation only at most NADP sites; temperature, precipitation, and humidity for all other networks; and wind and solar radiation for most networks.

[c]Active since 1948 but reliability questionable until 1990.

Table 1-9. Current aquatic and hydrologic monitoring in NGPN parks. Entity conducting monitoring is in parentheses.

Park	Water Quality	Hydrology/Geomorphology
Agate Fossil Beds NM	Niobrara R. macroinvertebrates (Prototype[a]) Drinking-water pollutants (Park)	Irrigation canal flow (NE) Niobrara R. flow (NE) Groundwater level (Park)
Badlands NP	Drinking-water pollutants (Park)	
Devils Tower NM	Drinking-water pollutants (Park)	Groundwater level (Park)
Ft. Laramie NHS	Laramie R. nitrates, temperature, water level, dissolved oxygen (USGS) Drinking water (Park)	Bay Well flow (WY) Laramie R. flow (USGS)
Ft. Union Trading Post NHS	Drinking-water pollutants (Park)	Bank erosion (Park)
Jewel Cave NM	Cave groundwater chloride and nitrate (Park) Drinking-water pollutants (Park)	Cave drip site drip-rate measurements
Knife R. Indian Villages NHS	None	Missouri R. flow (USGS) Bank erosion (Park)
Missouri NRR	Multiple parameters by multiple agencies	Missouri R. and tributary flow (COE, USGS) Channel profile and imagery (USGS)
Mount Rushmore NMEM	Drinking-water pollutants (Park)	Grizzly Creek peak flow (USGS)
Niobrara NSR	Niobrara R. and tributaries, multiple parameters (Park) 5-yr surveys of pH, dissolved oxygen, phosphorous, nitrates, nitrites (NE)	Niobrara R. flow (USGS) Flow (Park)
Scotts Bluff NM	None	None
Theodore Roosevelt NP	Drinking-water pollutants (Park)	Little Missouri R. flow and tributary peak flow (USGS)
Wind Cave NP	Beaver, Highland, and Cold Spring Creek temperature, turbidity, oxygen, conductivity, pH, and salinity (Park) Park springs water chemistry (Park) Drinking-water pollutants (Park) Cave water quality (Park)	Beaver Creek flow (USGS) Cave water level (Park) Well groundwater level (Park)

[a]Prototype = NPS Prairie Cluster Prototype Ecological Monitoring; NE = State of Nebraska; SD = State of South Dakota; WY = State of Wyoming; USGS = U.S. Geological Survey; COE = U.S. Army Corps of Engineers.

Development of the NGPN Vital Signs Monitoring Program

NPS-wide Monitoring Goals

The overall goal of natural resource monitoring in national parks is to develop scientifically sound information on the current status and long-term trends in the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems. All 32 I&M Networks have the following five goals for Vital Signs monitoring:

- Determine the status and trends in selected indicators of the condition of park ecosystems to allow managers to make better informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources
- Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management
- Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments
- Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment
- Provide a means of measuring progress toward performance goals

The approach of the NPS monitoring program is to select and monitor Vital Signs, defined as:

> A subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization including landscape, community, population, or genetic levels, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).

Because of the costs required to measure complex natural systems, Vital Signs can only include a relatively small number of elements and processes of interest to park units.

NGPN I&M Objectives

To develop an approach toward meeting I&M national goals as well as the needs of NGPN parks, the Network conducted resource inventories, determined general Network Priorities, selected Vital Signs to be monitored, and is developing monitoring protocols for these Vital Signs. In the process of developing monitoring priorities and evaluating potential Vital Signs (Figure 1-6), the Network is establishing general objectives for the monitoring program (Table 1-10). The objectives are based on National Park Service management policies (NPS 2006), GPRA goals, park-specific management concerns, and examination of natural and human changes affecting key resources in Network parks. In addressing these objectives, the NGPN follows a multi-faceted approach (Woodley 1993) by choosing Vital Signs that are indicators of ecosystem drivers (climate and weather), potential threats to resources (e.g., exotic species), focal resources (e.g., cave climate), and key ecological processes and properties (e.g., plant community composition, land cover). Many factors threatening park resources (e.g., invasive species and pollution) originate outside the parks. Furthermore, no single spatial or temporal scale addresses all key system components and processes. Therefore, Network monitoring focuses on attributes at the levels of watersheds and landscapes (land cover),

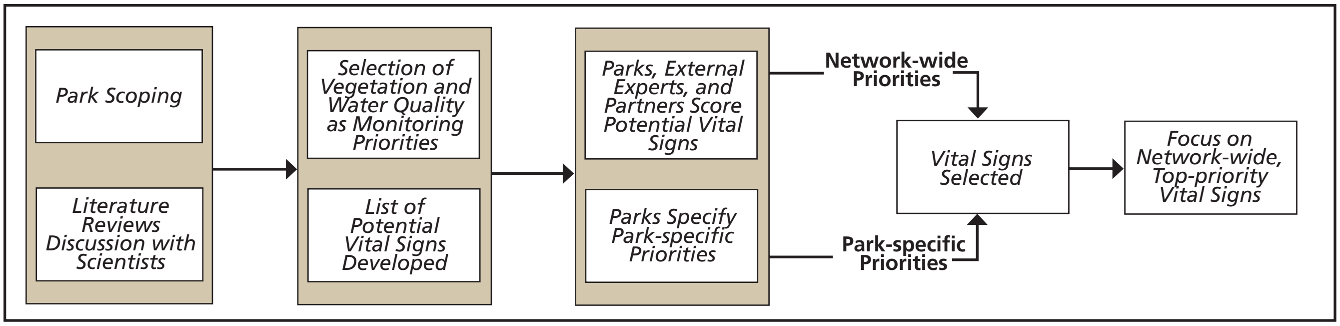


Figure 1-6. Overview of the NGPN's process for Vital Signs selection. See Chapter 3 for more information.

communities (terrestrial plants), and single-species occurrence (area occupied by prairie dogs). When feasible, monitoring is implemented as part of local, regional, and national partnerships.

The remainder of this plan outlines the proposed NGPN monitoring program and describes how it will achieve these NPS goals and Network monitoring objectives. Chapter 2 describes our use of conceptual models to summarize key aspects of the ecological context of this program, while Chapter 3 describes the Network's Vital Sign selection process in detail. Chapters 4–10 outline aspects of Network's sampling designs, protocols, data management, expected budgets, and reporting procedures to be used in monitoring Vital Signs.

South Bluff at Scotts Bluff National Monument

Table 1-10. General objectives for the NGPN monitoring program. Levels are from the NPS Ecological Monitoring Framework (NPS 2005*b*).

Level 1	Level 2	General NGPN Objectives
Air & Climate	Air Quality	Collaborate with other monitoring to determine regional air quality trends and to determine whether selected pollutants are in danger of reaching levels that may degrade other resources in each park.
	Weather & Climate	Ensure that daily records of temperature, precipitation, and wind are collected and available at each park for examining climatic trends and helping explain variability in other Vital Signs.
Geology and Soils	Subsurface Geologic Processes	Determine trends in cave climate, air flow, water levels, and water quality, and rapidly detect episodes of pollutant inputs into Wind Cave and Jewel Cave.
Water	Hydrology; Water Quality	Determine trends in water flow and availability, physical and chemical water quality characteristics, and macroinvertebrate community indices in streams, rivers, and springs of NGPN parks.
Biological Integrity	Invasive Species	Determine trends in abundance of exotic plants in Network parks, and rapidly detect new species of high concern.
	Focal Species or Communities - Vegetation	Determine trends in vegetation structure (cover of shrubs, grasses, herbs, and non-vegetated ground; diameter-density distribution and regeneration of trees) and composition (richness, diversity, functional group distribution; and ratio of exotic to native species) in Network parks.
		Collaborate with other NPS programs to examine effectiveness and effects of vegetation management programs (particularly prescribed fire and exotic-plant treatments).
		Determine correlations between trends in vegetation characteristics at the park level and potential drivers of change including management practices, climate, landscape patterns, and atmospheric chemical deposition.
		Determine trends in herbivore use and impacts on primary production and vegetation structure at selected locations in Network parks inhabited by large grazers.
	Focal Species or Communities - Animals	Determine landbird population and community-composition trends at the park and (in collaboration with other agencies) landscape levels.
		Determine changes in areas occupied by, or abundance of, black-tailed prairie dogs at the five NGPN units where present.
Landscapes	Landscape Dynamics	Determine changes in the distribution of plant communities and cover types within NGPN parks and document how these distributions are affected by management, natural disturbances, and other large-scale influences. Record occurrence, location, and area affected by fires, blow down, and other disturbances.
		Determine aggregated trends in cover types and gross land use (e.g., % urban, % agricultural) in the surrounding watersheds to assess broad-scale changes affecting water quality and quantity in park aquatic systems.
	Soundscape and Viewscape	At selected locations, determine trends in landscape visual characteristics (viewscapes and night sky) and natural and human-produced sounds.

Chapter 2
Conceptual Ecological Models

Those who collect data without building models run the very real risk of discovering, when they eventually analyze their data, that they have collected the wrong data!
—Starfield and Bleloch 1991:3

A conceptual model is a narrative, table, or diagram that summarizes key components, influences, and processes in an ecological system. These models are critical intellectual tools in developing monitoring programs (Barber 1994; Noon et al. 1999; National Research Council 1995; Busch and Trexler 2003). Conceptual models are intended to stimulate thought and discussion about which data we will collect, how these data will be interpreted, and what this information may mean to park management. The modeling process is a bootstrap approach for exploring potential monitoring priorities, for developing monitoring strategies that will meet the goals outlined in Chapter 1, and for improving our understanding of Network ecosystems (Starfield and Bleloch 1991). We start by describing what we know about a system, and then integrate work of other scientists and managers to address limitations in our individual knowledge. This benefit is important particularly because ecological interactions transcend the disciplinary specializations of scientists designing monitoring programs (Allen and Hoekstra 1992). Modeling forces us to make transparent our assumptions about how the Network systems work and why our monitoring objectives are high priorities.

In developing conceptual models, the NGPN initially focused on a small set of models for assisting with selection of Vital Signs. Conceptual models subsequently have been developed as fundamental tools in exploring and justifying potential monitoring objectives for each Vital Sign (Appendix B). Conceptual modeling is an ongoing process in the Network, one that is an important step in the development of our individual monitoring protocols. As a result, we do not provide a full completed suite of conceptual models. Rather, this chapter provides examples of several types of conceptual models that the Network has used so far in developing monitoring priorities and protocols.

General Ecological Model as Context for Detailed Models

We developed a simple overall model to categorize major ecosystem components and to show the dominant influences on all Network ecosystems to help provide a context for detailed models (Figure 2-1). These influences are discussed in Appendix B.

Western Tanager (*Piranga ludoviciana*), photo by Doug Backlund.

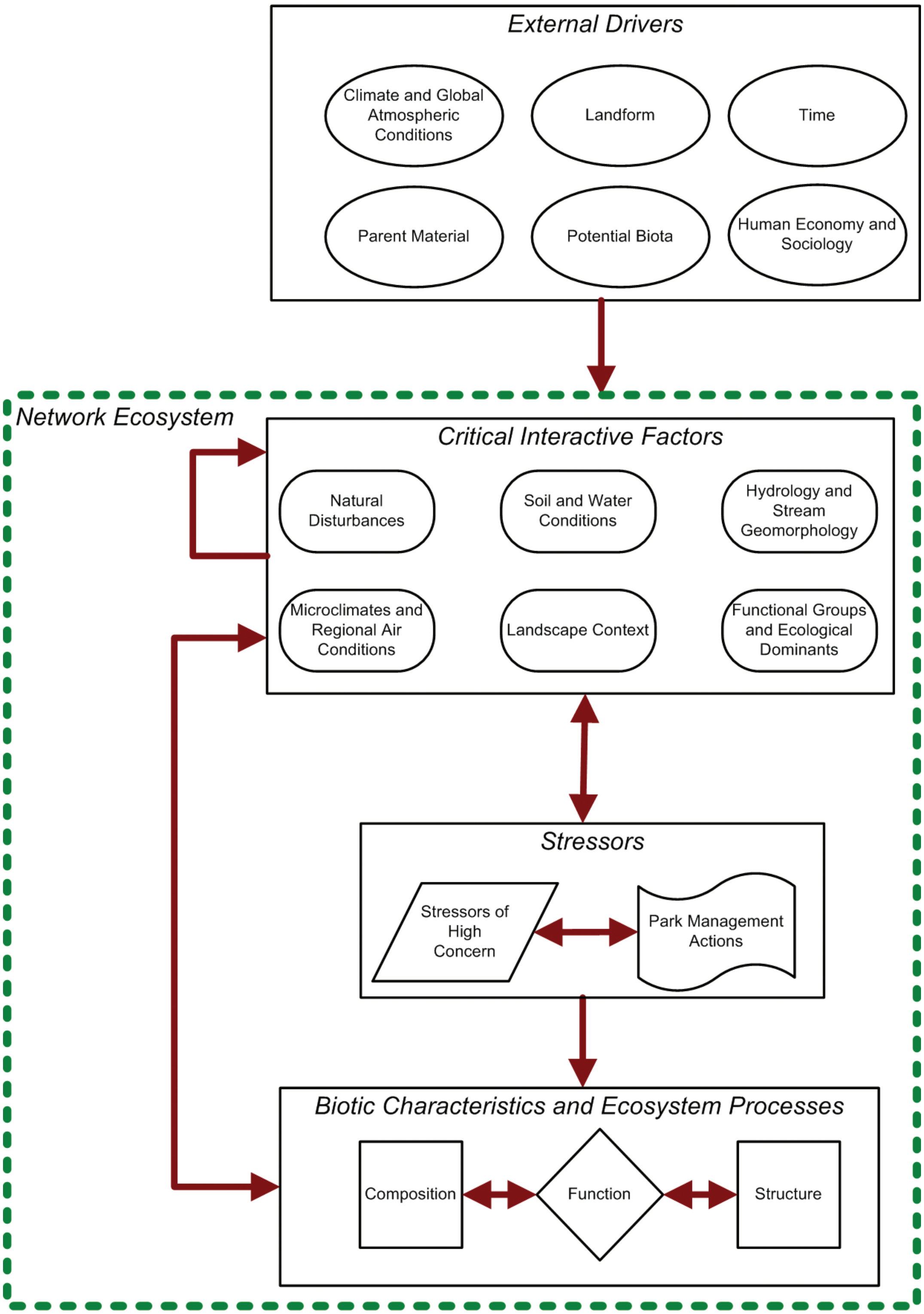


Figure 2-1. General model for factors shaping ecosystems in the NGPN.

The primary purpose of the Network's general model is to summarize three major categories of factors structuring and causing changes in NGPN ecosystems:

1. Drivers are external forces that have large-scale influences on NGPN ecosystems. They determine what type of ecosystem can form in a place (Dale et al. 2000) and constrain processes such as energy flow. They operate at much larger spatial scales than that of any individual park.

2. Some major influential factors are part of a park's ecosystem structure and function, rather than being largely external (Jenny 1941; Chapin et al. 1996). Changes in these factors may cause significant changes in vegetation composition and structure, faunal community composition, and nutrient dynamics within a park. Conversely, there may be feedback and interactions among these influential factors and with other components of the ecosystem: for example, a low-intensity fire that reduces tree density may decrease the likelihood of a more severe fire or insect outbreak.

3. Stressors are either human-caused perturbations or natural influences occurring at excessive or deficient levels (Barrett et al. 1976:192). Defining important Network stressors and potential impacts of these threats has been a primary emphasis in the development of the Network's monitoring program. Stressors of high concern directly affect disturbance regimes, hydrology, and other influences discussed above (e.g., altered fire regimes; altered river flows) because such stressors may affect all finer scale processes and components of NGPN ecosystems.

Stressor Models

In the process of selecting Vital Signs, the NGPN identified and described major stressors of concern, outlined the general spatial scale at which each stressor operates, and summarized which resources were most sensitive to each stressor. Several major stressors operate at both within-park and larger spatial scales. For example, populations of exotic species may be reduced in parks, but external source populations may lead to continued invasion. Some stressors mainly operate at larger spatial scales or originate from human activities outside of parks, including global atmospheric changes, pollution (apart from internal pollutants such as herbicides used for exotic-species control), landscape changes, and alteration of hydrology and stream geomorphology (apart from within-park channel characteristics affected by bank stabilization). To understand better how these stressors may affect park resources, the Network continues to develop tabular or graphical models summarizing and predicting the expected impacts of stressors on specific Vital Sign resources. Such models include broad diagrams primarily intended to communicate major stressor categories for a particular ecosystem type (Figure 2-2), as well as more detailed summaries of stressors and impacts affecting a specific resource (Table 2-1).

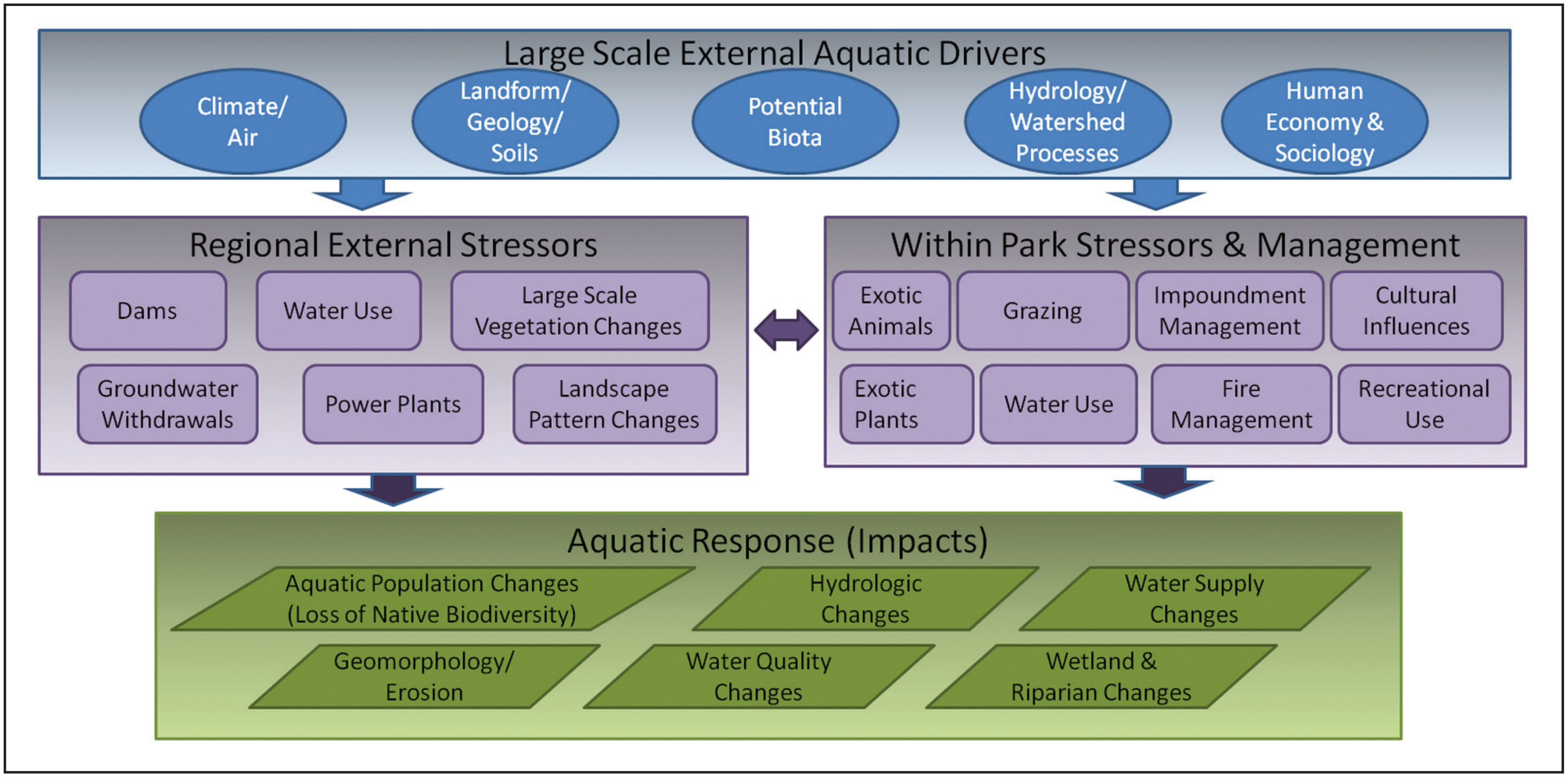


Figure 2-2. Drivers and major stressors of NGPN aquatic systems. Developed by U.S. Geological Survey South Dakota Water Science Center.

Table 2-1. Stressor impacts on terrestrial and riparian vegetation of the NGPN.

Stressor Category	Specific Stressor	Impacts	Indicator
Global atmospheric changes	Climate change	Shifts in composition, population size, and species distributions	Community composition; population size and distribution of rare species
Altered disturbance regime	Fire suppression	Changes in forest and grassland species composition; successional change in forest type; increased woody component and decreased heterogeneity in grasslands	Composition; distribution of plant community types; woody species composition and age distribution
Altered hydrology and geomorphology	Dams and altered hydrology	Shifts in riparian community composition and productivity; decreased recruitment of phreatophytes	Composition and biomass; phreatophyte regeneration
	Canal seepage	Increased habitat for wet and mesic species and communities	Composition; distribution of plant community types
	Groundwater withdrawals	Shifts in riparian community composition and productivity; lack of phreatophyte recruitment	Composition and biomass; phreatophyte regeneration
Chemical inputs and pollution	Airborne pollution	Toxicity (for species sensitive to ozone and other pollutants); shifts in community composition; increased productivity due to fertilization; decreased vigor, increased mortality, and decreased seed production due to pesticides	Plant biomass or cover; seed production; specific symptoms of sensitive species; biomass and composition
	Animal waste/ sedimentation	Surface water pollution	Composition and biomass
	Groundwater pollution	Decreased vigor; lack of recruitment by riparian trees	Phreatophyte regeneration
	Surface water pollution	Shifts in riparian and aquatic plant community composition and productivity due to fertilization; decreased vigor or mortality due to toxic inputs	Composition and biomass
Landscape changes	Development adjacent to park	More sources of exotic species; changes in ungulate populations; increased air pollution	Composition; distribution of plant community types
	Other adjacent uses	Agriculture, recreation, and grazing increase sources of exotics; timber harvest changes the fire regime	Composition; distribution of plant community types
	Isolation and fragmenation	Populations of rare species lost to stochastic events are not replaced; decreased reproduction due to inbreeing effects; fire suppression	Composition; rare species population distribution; genetic diversity
	Soil erosion in watersheds	Altered size and distribution of habitats for rare species and communities in erodable zones	Distribution of plant community types; size and distribution of populations

Table 2-1. Stressor impacts on terrestrial and riparian vegetation of the NGPN (continued).

Stressor Category	Specific Stressor	Impacts	Indicator
Human use of parks and management	Visitor use and infrastructure	Increased movement corridors and sources for exotic and ruderal species; soil compaction and erosion; fragmentation of remnant communities	Composition in disturbed areas
	Past land use	Increased ruderal plant component from disturbed sites	Composition in/around disturbed areas
	Prescribed fire	Prevention of woody species establishment; temporary decreased productivity (in mixed-grass prairie); increased landscape heterogeneity with variable fire regime; interactions with grazing	Composition; distribution of community types; beta-diversity
	Mechanical thinning	Lower intensity fires leading to maintenance of woodland/forest communities	Forest/woodland composition and structure; fuel load structure and distribution
	Exotic plant species	Elimination or reduced density and distributions of exotics; return to pre-invasion conditions	Target and nontarget species density and distribution; composition, diversity, and structure
	Restoration plantings	Increased diversity and abundance of natives; decreased abundance of non-natives	Composition and diversity
	Water developments for grazers	Concentrated areas of low or no vegetation cover; increased habitat for ruderal species	Composition and cover in disturbed areas
	Harvest and collection	Decrease in collected species	Composition and distribution of target species
	Management of grazers	Changes in landscape heterogeneity and abundance of grazing-sensitive and intolerant species	Composition, diversity, and structure; distribution/diversity of communities
	Bank stabilization	Riparian plant communities static or succeeding	Distribution of community types; composition
Exotic species	Invasive plants	Displacement of native species; alteration of community composition, structure and diversity	Composition and structure; rare species population size and distribution
	Invasive animals	Shifts in community composition and biomass	Composition and biomass
Altered animal abundance	Missing grazers and other species	Decreased landscape heterogeneity; increased cover; increase in sensitive/intolerant species; decreased diversity compared to light and variable grazing; altered grazer/fire interactions	Composition, diversity, and structure; distribution of community types; beta-diversity
	Overabundant herbivores	Altered woodland composition and understory structures	Understory composition and structure

Detailed Ecosystem Models

Detailed ecosystem models show key components and processes in a major aquatic or terrestrial ecosystem of the NGPN. For example, the detailed model for stream/river systems (Figure 2-3; modified from Scott et al. [2005]) outlines the organization of riverine systems and shows links with riparian and upland ecosystems. Further consideration of such links within and among major ecosystem types in the Network will be of high importance as we develop monitoring protocols; by examining these links we can better consider ways of integrating monitoring among multiple Vital Signs.

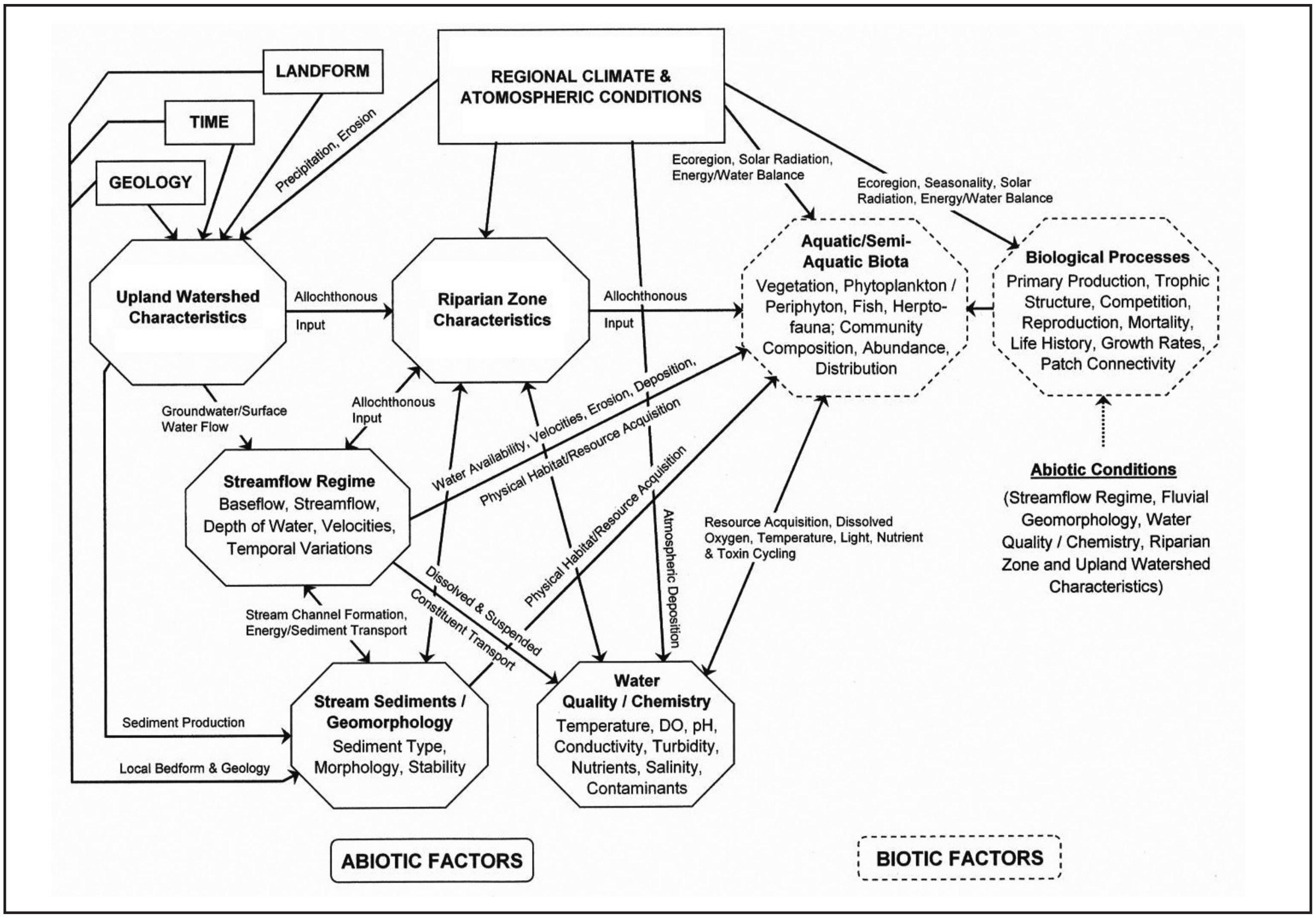


Figure 2-3. Ecosystem model for riverine systems.

Rectangles indicate major drivers of ecosystem change and variability. Octagons indicate major ecosystem components and processes (attributes). Arrows indicate ecosystem stresses and responses (functional relationships). The model is constrained by global climatic and atmospheric conditions, topography, parent (geologic) material, and potential biota. Source: NPS (2008*b*); modified from Scott et al. (2005).

State-transition Models for Vegetation Communities

To summarize factors affecting vegetation characteristics across major NGPN ecological site types, we developed state-transition models for four general grassland site types; three Black Hills and foothills forest/savanna site types; shrublands; green ash draws; juniper draws/slopes; and floodplain sites (Appendix B; see example in Figure 2-4). These state-transition models attempt to describe the general range of structural conditions and characteristic dominant species on a site under 20th–21st century conditions. In addition, the models show expected changes across ecological thresholds to new states; such transitions are difficult or impossible to reverse and can represent semi-permanent degradation of the ecosystem (e.g., Briske et al. 2005). Such threshold changes may be caused by alteration of historic disturbance regimes, exotic invasion, prolonged climate change, and other stressors.

By developing state-transition models applicable to the central and western NGPN, we clarified several aspects of our understanding of these ecosystems.

- Contrary to grasslands in many regions worldwide, Network grasslands appear to have been highly resilient to large changes in grazing, precipitation, and other disturbances over the last one or two centuries. At least in terms of general structure and dominant species, these grasslands have not crossed major thresholds in the last 100 years during periods of high cattle grazing (historically in some NPS units and currently in some surrounding areas) or prolonged drought.

- Exotic species now are ubiquitous in most ecosystems. It is unclear whether Network ecosystems will continue to be resilient or whether times of high disturbance that allow invasive species to colonize sites will produce new transitions that are difficult or impossible to reverse.

- Unlike many grassland areas of the world, encroachment of woody vegetation has not been a major problem for Network grasslands outside of the Black Hills foothills, Niobrara NSR, and Missouri NRR. Conceivably, 21st century changes in precipitation patterns could alter this pattern and lead to increase risk of transitions across thresholds to stable woody dominated states.

- In Black Hills forests, as in dry forest types throughout most of western North America, absence of fire over the last century has led to greatly increased tree density and expansion of woodlands into meadows. This problem is exacerbated in the Black Hills, because growing-season precipitation often is sufficient to allow high rates of successful seedling establishment. The Black Hills has changed from a system historically characterized by frequent low-severity fires and infrequent or localized moderate- to high-severity fires into a system with high risk of large-scale severe fires and widespread insect outbreaks. Managing forests, such as at Mount Rushmore NMEM, to be in more stable states will require continued expensive thinning, burning, and other treatments.

- Dam control of river flows is leading to loss of floodplain woodlands in many parts of the Network. Across the region, many floodplain woodlands are succeeding to grasslands and shrublands as residual large cottonwoods die and are not replaced by regenerating trees.

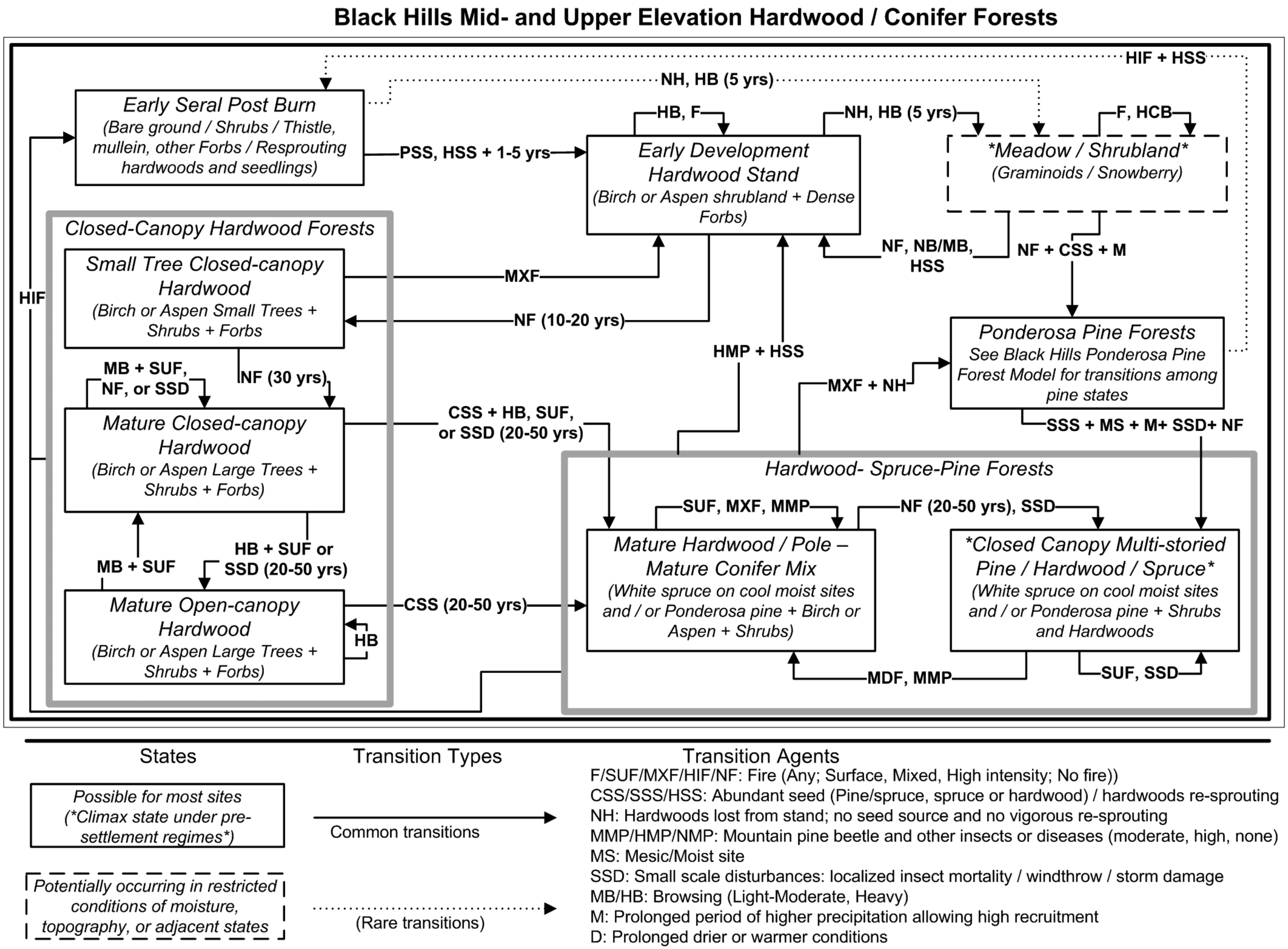


Figure 2-4. State-transition model for forests at upper elevations of the Black Hills.

Broad-scale Park-wide Conceptual Diagrams

Previously discussed models are most appropriate for internal use or to facilitate discussion among scientists and resource managers. The NGPN in partnership with the University of Maryland Center for Environmental Science (UMCES) has developed conceptual diagrams for several parks to emphasize broader overviews of important ecosystem components and processes and to suitably communicate these overviews to nontechnical NPS audiences and the public. Rather than focusing on a specific ecosystem or natural resource, these diagrams provide an integrated park-wide picture. Moreover, they are developed interactively through numerous discussions among UMCES staff, Network I&M core staff, park resource experts, park interpreters, and other park staff. Although focusing on four parks, the initial conceptual diagrams developed by UMCES and the Network (Figure 2-5; Appendix B) cover major ecosystems of the Network, including mixed-grass prairie, restored grasslands, Black Hills forests, caves, and riverine systems; therefore, these diagrams summarize resources and processes important throughout the NGPN.

Berry Falls at Niobrara National Scenic River

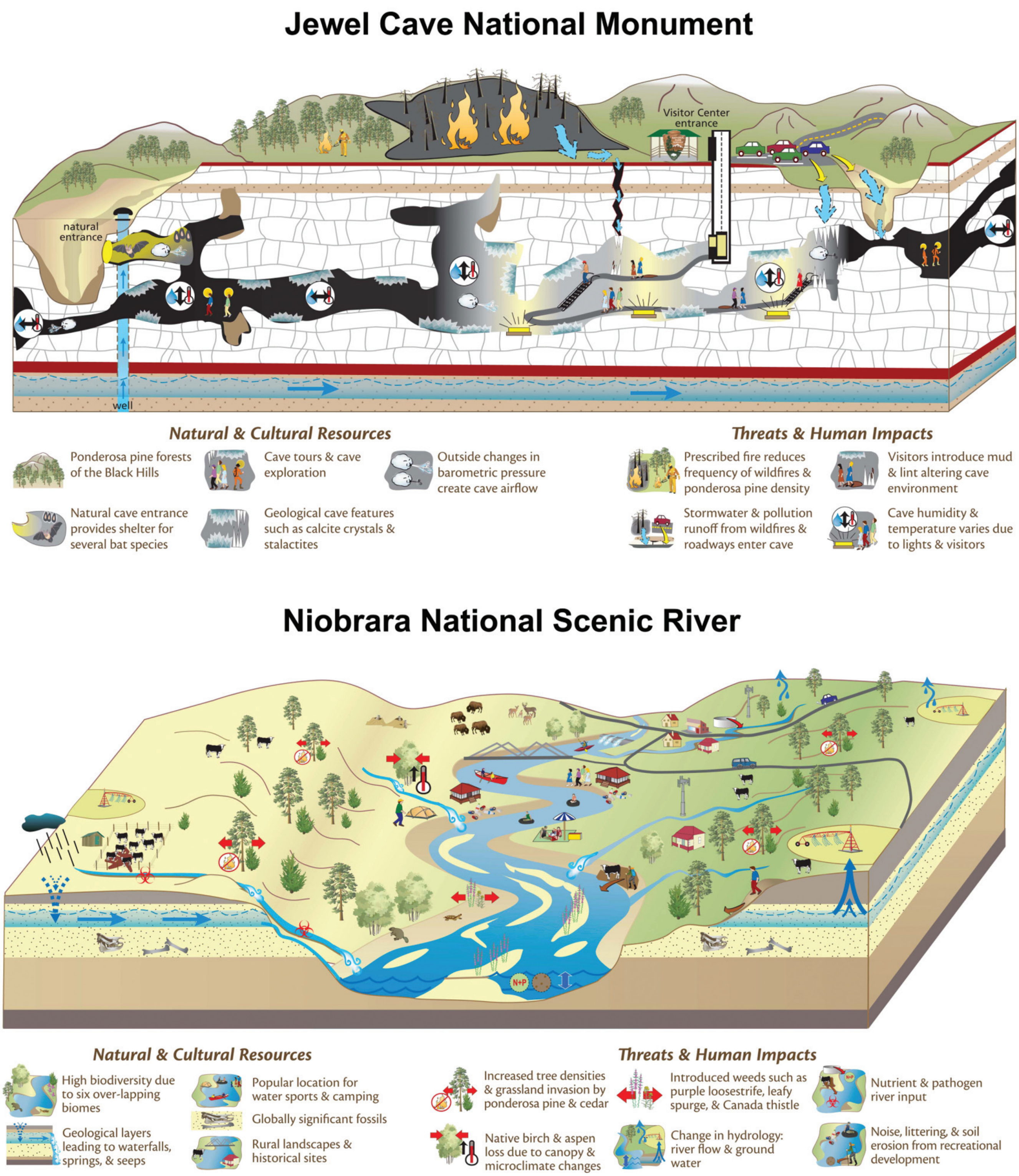


Figure 2-5. Conceptual diagrams for Jewel Cave NM and Niobrara NSR.

Prepared by University of Maryland Center for Environmental Science, in collaboration with Jewel Cave NM, Niobrara NSR, and NGPN I&M core staff.

Chapter 3
Prioritization and Selection of Vital Signs

The NGPN seeks to monitor the overall ecological condition of the Network's parks, determine status and trends for resources of high importance to humans, and quantify key properties of drivers and stressors affecting these park resources. Given available funding, the Network had to carefully prioritize Vital Signs by considering what information will be most useful to park managers as they work to maintain park resources over the next century. Moreover, our choice of Vital Signs reflected our need to leverage funding by taking advantage of partnerships and opportunities to use relevant data already being collected by parks and other programs in the region. This chapter briefly summarizes the process used for selecting NGPN Vital Signs (Table 3-1), and describes the selected Vital Signs.

Missouri River at Missouri National Recreational River

Brief Overview of NGPN Vital Signs Selection

- In 2005, NGPN I&M core staff, park Technical Committee representatives, and a mix of other Network staff, partners, and scientists ranked 125 potential Vital Signs based on five general criteria: relevance to national I&M goals; management significance; ecological significance; feasibility; and value to partners (Appendix C). Because a primary goal of the I&M Program is to help provide the scientific data and information needed by parks for making resource management decisions, the Network avoided selecting indicators with little direct relevance to park management. Conversely, the Network dropped some preliminary Vital Signs because these attributes were not strong indicators of each park's broader ecological condition.

- The Network selected vegetation and water quality as high-priority Vital Signs early in the selection process. Vegetation characteristics are of high concern to managers, are good indicators of ecosystem condition (see Chapter 2), and are strongly affected by many stressors. Congress granted funding specifically for water quality monitoring, based on the need for the NPS to meet water quality standards under the Clean Water Act.

- Based on prioritizations made during Vital Sign selection and conceptual-model development, the Network identified some attributes as Vital Signs that would continue to be monitored without I&M funding.

The final list of NGPN Vital Signs (Table 3-2) reflects the background reviews and inventories conducted by the Network, rankings made at the Vital Signs selection workshop, subsequent discussions and evaluation, and finally, the professional judgment of Network staff.

Table 3-1. Primary steps in selecting Vital Signs for the NGPN.

Time Period	Lead Entity	Description
July 2002–April 2004	NGPN I&M Core Staff	Held 12 park-specific scoping meetings with park staff to introduce the I&M Program, discuss park resources and stressors, summarize current monitoring, and identify potential Vital Signs.
2002–2003	NGPN I&M Core Staff, Technical Committee (TC), Board of Directors	Concluded that vegetation and water quality would comprise top-priority Vital Signs.
July 2003–May 2004	Dr. Amy Symstad, USGS Northern Prairie Wildlife Research Center	Reviewed current vegetation monitoring, resources, and stressors. Sent questionnaire to all parks to gather information about stressor impacts and to rank potential vegetation monitoring projects (Symstad 2004).
August 2003–August 2005	Dr. Nels Troelstrup, South Dakota State University	Met once with staff of each park to discuss water resources and management issues. Conducted baseline water quality sampling; developed and evaluated potential macroinvertebrate indices of aquatic conditions. Formed list of potential aquatic Vital Signs.
October 2003–March 2005	NGPN Coordinator	Met five times with program managers from the Northern Great Plains Fire Ecology Program (FireEP) and the Northern Great Plains Exotic Plant Management Team (EPMT) to determine Vital Signs relevant to all three programs. Met seven other times to coordinate the three programs, twice with national-level staff of the NPS Fire Ecology program.
2003–2005	David Pohlman, NPS	Gathered existing information and summarized air quality conditions in the NGPN. Made recommendations about potential air quality Vital Signs and monitoring projects.
Summer 2005	NGPN Coordinator and TC	Developed list of 125 potential Vital Signs; park staff scored these for management significance (Appendix C).
September 2005	NGPN I&M Core Staff and Park Staff	Conducted Vital Signs selection workshop with Network staff, outside experts, and partners. The Network reviewed scores and selected Network-wide Vital Signs.
September–November, 2005	NGPN Coordinator and TC	Parks provided list of high-priority concerns that were not Network-wide priorities. Vital Signs were selected to address these needs.
December 2007– July 2008	NGPN I&M Core Staff and TC	Network revisited park-specific priorities that lack strong ecological justification and determined non-I&M monitoring efforts that would be considered Vital Signs.

Table 3-2. Vital Signs to be monitored by the NGPN.

See bottom for symbol codes. Orange = I&M Program will implement protocols for data collection from at least one park and for reporting; green = I&M Program will implement protocols for data access/reporting from monitoring performed by other entities; white = no I&M protocols to be developed; Gray = deferred.

Vital Sign Category	Vital Sign	Examples of Measures [Primary entity conducting monitoring if not I&M]	AGFO	BADL	DETO	FOLA	FOUS	JECA	KNRI	MNRR	MORU	NIOB	SCBL	THRO	WICA
Air and Climate	Ozone	Peak summer levels (parts per million) [NPS Air Resources Division (ARD)]	◊	•	◊							◊	◊	•	•
	Wet and Dry Deposition	Nitrogen and mercury deposition [ARD]	◊	•	◊							◊	◊	•	•
	Visibility and Particulate Matter	Amount of fine particles [ARD]		•										•	•
	Air Contaminants	Sulfates [ARD]		•										•	•
	Weather and Climate	Temperature, precipitation, wind speed [Numerous]	•	•	•	•	•	•	•	•	•	•	•	•	•
Geology and Soils	**Stream and River Channel Characteristics**	**Bank slope, channel width/depth, channel location**	✚	✚	✚	✚	✚		✚	✚	✚	✚	✚	✚	✚
	Cave Meteorology	**Temperature, airflow speed/direction**						✚							✚
Water	Groundwater Dynamics	Aquifer/well water level [Parks; Resource Districts]	•		•			•				•	•		•
	Surface Water Dynamics	Stream discharge and level [USGS]	•	•	•	•	•		•	•	•	•	•	•	•
	Surface Water Chemistry	**Temperature, specific conductivity, pH**	✚	✚	✚	✚		✚	✚	✚	✚	✚	✚	✚	✚
	Cave Water Chemistry	**Temperature, specific conductivity, pH**						✚							✚
	Aquatic Contaminants	**Levels of mercury, atrazine, arsenic**	✚	✚	✚	✚		✚	✚	✚	✚	✚	✚	✚	✚
	Aquatic Microorganisms	**Levels of fecal coliform**	✚	✚	✚	✚		✚	✚	✚	✚	✚	✚	✚	✚
	Aquatic Macro-invertebrates	**Richness; metrics for selected taxonomic groups**	✚	✚	✚	✚		✚	✚	✚	✚	✚	✚	✚	✚

Table 3-2. Vital Signs to be monitored by the NGPN (continued).

Vital Sign Category	Vital Sign	Examples of Measures [Primary entity conducting monitoring if not I&M]	AGFO	BADL	DETO	FOLA	FOUS	JECA	KNRI	MNRR	MORU	NIOB	SCBL	THRO	WICA
Biological Integrity	**Exotic Plant Early Detection**	**List of high-priority encroaching species**	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚
	Forest Insects and Diseases	Area of mortality from mountain pine beetles [USFS]			•			•			•				•
	Riparian Lowland Plant Communities	**Species richness, total cover, proportion total cover that is nonnative, tree density by diameter class**	✚		✚	✚			✚	✚		✚	✚	✚	✚
	Upland Plant Communities	**Richness, proportion of cover that is nonnative, tree density**	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚
	Land Birds	**Density or occupancy of selected species, community composition**	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚	✚
	Raptors	Number of active nests and net number fledged [Parks; one to two species per park]		•	•					•				•	•
	Prairie Dogs	**Total area and distribution of active colonies**		•	•								✚	•	•
	Ungulates	Number of bison rounded up or observed [Parks]		•										•	•
	Piping Plovers and Interior Least Terns	Number of active nests and net number fledged [Parks]								•		•			
	Black-footed Ferrets	Abundance [Parks; USFWS]		•											•
	Pallid Sturgeon	Capture rates [COE/ USGS/USFWS/SD]								•					

Table 3-2. Vital Signs to be monitored by the NGPN (continued).

Vital Sign Category	Vital Sign	Examples of Measures [Primary entity conducting monitoring if not I&M]	AGFO	BADL	DETO	FOLA	FOUS	JECA	KNRI	MNRR	MORU	NIOB	SCBL	THRO	WICA
Human Use	Treatments of Exotic Infestations	Location, area, and target species of herbicide treatments [EPMT, Parks]	•	•	•	•	•	•	•	•	•	•	•	•	•
	Visitor Use	Number of visitors entering park [Parks]	•	•	•	•	•	•	•	•	•	•	•	•	•
Landscapes (Ecosystem Pattern and Processes)	Fire and Fuel Dynamics	Spatial extent and severity of prescribed fires; dead and down fuel loads [FireEP, Parks]	•	•	•	•	•	•	•	◊	•	◊	•	•	•
	Land Cover and Use	**Land use and coarse vegetation cover in parks and ~1-mi. buffer**	+	+	+	+	+	+	+	+	+	+	+	+	+
	Extreme Disturbances	**Characteristics and location of blowdowns, floods, large debris slides, and other major disturbances**	+	+	+	+	+	+	+	+	+	+	+	+	+
	Soundscape	**Sound pressure; percentage of total sound from natural sources**	+	+	+	+	+	+	+	+	+	+	+	+	+
	Viewscape	Photos used for analysis of viewshed changes	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊
	Night Sky	Lumens of anthropogenic light	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊

+ Vitals Signs for which the NGPN will develop protocols and implement monitoring using funding from the Vital Signs or water quality monitoring programs.

• Vital Signs being monitored by a Network park, another NPS program, or by another federal or state agency using other funding. The Network will collaborate with these other monitoring efforts.

◊ Vital Signs likely to be monitored in the future, but not currently monitored due to limited staff and funding.

(no symbol) Vital Sign does not apply to park, or was not identified as a high priority for monitoring.

Vital Signs in the Context of NGPN Conceptual Models

Chapter 5 provides general justification for Vital Signs and their associated protocols being developed by the Network. Our understanding of the importance of these Vital Signs partially results from ongoing discussions among experts and literature reviews that form the basis for NGPN conceptual models. In Table 3-3, we summarize links between NGPN Vital Signs and specific conceptual models presented in Chapter 2 and Appendix B. A few Vital Signs are not covered in significant detail by our current suite of conceptual models; these Vital Signs (e.g., Land Birds) will be examined further as we continue to develop conceptual models as an important part of protocol development.

Potential Adjustments to NGPN Vital Signs

The Network's top priorities are Vital Signs for which we are currently developing protocols (Table 3-2), including all Vital Signs for which the I&M Program will be the lead on monitoring, plus selected Vital Signs such as Weather and Climate and air quality Vital Signs for which we will develop protocols for data access and reporting (summarized in Chapter 5). Our next priorities are Vital Signs that may require additional funding or staff to develop protocols and implement monitoring (Night Sky and Viewscape; Table 3-2). If additional resources become available, the NGPN would consider adding additional Vital Signs beyond those currently identified. Based on rankings during the 2005 Vital Signs selection meetings these might include:

- Soil erosion (if not indexed by variables collected during vegetation monitoring) or soil nutrients
- Expanded monitoring of raptor communities at selected parks
- Fish health, community composition, or bioaccumulants (currently there is multi-agency monitoring of native fish species abundance and composition in parts of MNRR, but it is unclear whether this will continue long-term)
- Beetle community composition

Given budget realities, however, it is unlikely that the NGPN will expand its list of Vital Signs. The Network subscribes to the National I&M Program's philosophy that funding should be used to monitor a few things well rather than many things inadequately. As protocols are developed, the Network might need to reduce the number of Vital Signs it monitors or the scope of its objectives for some Vital Signs so that we can adequately monitor plant communities, aquatic conditions, and a few other top priorities.

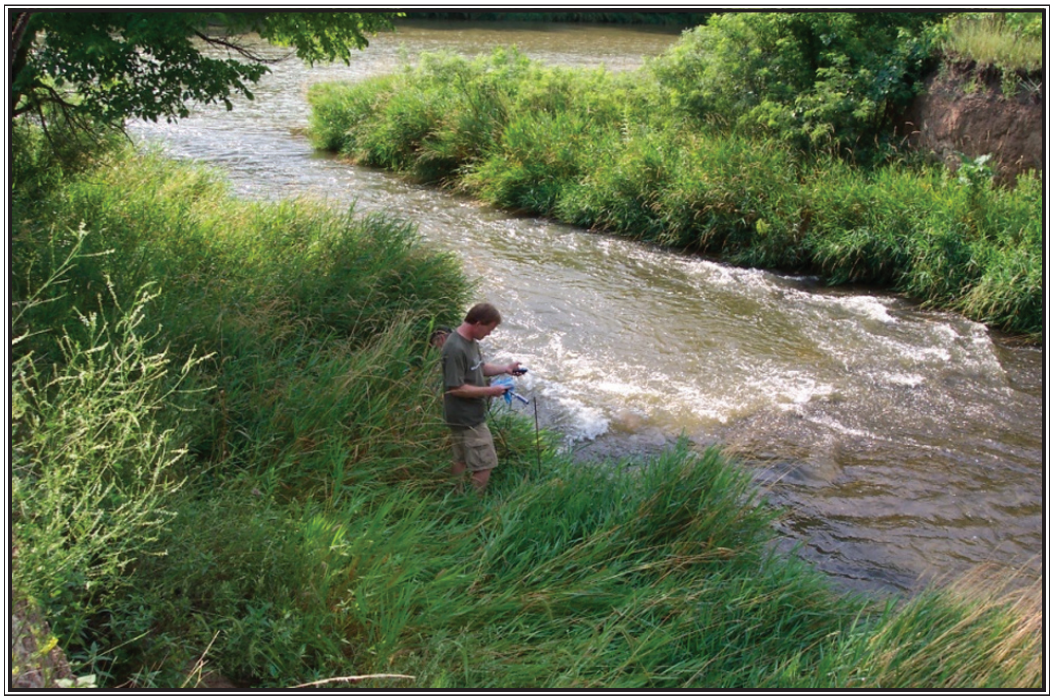
Table 3-3. Vital Signs in relation to NGPN conceptual models.

Vital Sign	Role in NGPN Conceptual Models	Relevant Models
Ozone	High levels can damage or kill susceptible plant species.	Table 2-1
Wet and Dry Deposition	Potential stressor of plant communities, particularly if nitrogen fertilization could lead to altered species composition.	Table 2-1; Figure B-6 (narrative)
Visibility and Particulate Matter	Stressor causing degradation of high-quality viewscapes, which are important resources for park visitors.	Figures B-7, B-8
Air Contaminants	Potential stressor of vegetation and aquatic biota.	Table 2-1; Figure 2-2
Weather and Climate	Fundamental driver of Network ecosystems.	All (e.g., Figure B-4)
Stream and River Channel Characteristics	Modeled as a fundamental component of riverine systems affecting aquatic conditions and riparian vegetation structure.	Table B-7; Figures 2-3, B-8, B-23
Cave Meteorology	Stable interior climate is a fundamental attribute of Jewel Cave and Wind Cave. Changes could affect other cave resources.	Tables B-3, B-4, B-6; Figure 2-5
Groundwater Dynamics	Changes in groundwater levels due increasing regional water use are a potential stressor of riparian vegetation communities, and may affect hydrology of streams, rivers, springs, and caves.	Tables 2-1, B-3, B-5, B-6, B-7; Figures 2-3, 2-5, B-9, B-10
Surface Water Dynamics	Changes in stream/river flows can cause major changes in the composition and structure of aquatic and riparian systems.	Table B-7; Figures 2-3, B-8, B-10, B-22, B-23
Surface Water Chemistry	Includes core water quality attributes affected by natural events and stressors; changes may impact aquatic and riparian biota.	Tables 2-1, B-7; Figures 2-3, B-10
Cave Water Chemistry	Changes in water quality in Jewel Cave and Wind Cave provide warning of pollutants entering the region's ground water.	Tables B-3, B-6; Figure 2-5
Aquatic Contaminants	Stressors of aquatic and riparian biota.	Tables 2-1, B-7; Figures 2-3, B-10
Aquatic Microorganisms	Stressors of aquatic and riparian systems; may cause human-health concerns for visitors using streams and rivers.	Table B-7; Figures 2-2, B-10
Aquatic Macroinvertebrates	Indicators of changes in water quality, riparian inputs, and stream/river flow.	Table B-7
Exotic Plant Early Detection	Exotic plants are modeled as one of the primary threats to NGPN vegetation communities. Early detection is the best strategy for preventing establishment of additional species.	Figure B-28
Forest Insects and Diseases	Modeled as an important disturbance agent in Black Hills ponderosa pine forests. Increased risk of high-severity outbreaks of mountain pine beetles threatens MORU old-growth forests.	Figures B-25, B-26, B-27
Riparian Lowland Plant Communities	Invasive species and reduction/elimination of flooding have greatly altered composition and structure (through loss of woody recruitment) of NGPN lowland areas. Riparian systems are the link between upland areas and riverine systems.	Figures 2-3, B-8, B-10, B-22, B-23

Table 3-3. Vital Signs in relation to NGPN conceptual models (continued).

Vital Sign	Role in NGPN Conceptual Models	Relevant Models
Upland Plant Communities	Respond to integrated effects of grazers, fire, insects, natural climatic variation, soil conditions, and most stressors affecting Network parks. Structure/production of these communities partially determine habitat availability/food for animal species, inputs into soil sub-systems, risk of severe fire, runoff into riparian/stream systems, and landscape visual characteristics.	Table 2-1; Figures 2-3, B-11 thru B-21, B-25 thru B-29
Land Birds	Species of high visitor and management interest; affected by changes in vegetation structure, landscape composition, and other within-park and external influences.	Figures B-6 (narrative), B-11
Raptors	Not covered explicitly by current models; selected because they are species of special management interest at some parks.	
Prairie Dogs	Prairie dogs have major influences on grassland vegetation and faunal communities and are an important management issue.	Table 2-1; Figures B-11, B-14, B-15, B-29
Ungulates	Grazing is a fundamental process in mixed-grass ecosystems. Either high prolonged grazing and browsing or absence of grazers is a major stressor of Network vegetation communities.	Table 2-1; Figures B-11 thru B-17, B-29, B-30
Piping Plovers and Interior Least Terns, Pallid Sturgeon	Federally listed species that are sensitive to changes in Missouri River and Niobrara River flow regimes and sediment dynamics.	Figure B-32 (narrative)
Black-footed Ferrets	Re-introduced species dependent on prairie dogs.	Figures B-7, B-29 (narrative), B-30
Treatments of Exotic Infestations	Direct and unexpected effects are potential stressors. If vegetation monitoring sites are in treated areas, data can be used to examine post-treatment changes in vegetation.	Table 2-1; Figures B-6 (narrative), B-7, B-14 thru B-19
Visitor Use	Stressor of aquatic, cave, and terrestrial systems.	Tables 2-1, B-3; Figures 2-5, B-6 (narrative)
Fire and Fuel Dynamics	Modeled as key processes in grassland and forest systems; affects inputs into aquatic systems. Altered fire regimes are primary stressors in many parks; prescribed fires and other fuels treatments are major management activities.	Tables 2-1, B-3; Figures 2-2, B-11 thru B-13, and most other models
Land Cover and Use	The landscape context of parks is a major influence on park ecosystems; major park-wide changes in vegetation structure are captured through this Vital Sign.	Tables 2-1, B-3; Figures B-6 (narrative), B-7 thru B-11, B-29
Extreme Disturbances	Rare disturbances not covered by other Vital Signs (e.g., major floods) may have long-term effects on Network ecosystems.	Table 2-1; Figure 2-3
Soundscape	Important resource for visitors and Native Americans using parks for traditional practices; degraded by vehicles, trains, airplanes/helicopters, and other human uses.	Figure 2-5
Viewscape, Night Sky	Important resource for NGPN visitors; potentially degraded by pollution and altered land uses outside of parks.	Figures B-7, B-8

Chapter 4
Sampling Design



Sampling water quality on the Niobrara River

This chapter provides an overview of the sampling designs for monitoring NGPN Vital Signs (Table 4-1), specifying how we will choose monitoring sites from the target population within each park (Thompson 2002) and the schedule for collecting data from these sites. The target population is the collection of resources or portion of each park for which we wish to make statistical inference about status and trend (Särndal et al. 1992). Long-term monitoring of NGPN Vital Signs must have clear objectives and be designed to make efficient and defensible statistical inference to meet these objectives. Because changes in our long-term funding, objectives, and understanding of park resources are certain to occur, sampling designs must provide some flexibility to change without losing the value of data collected up to that point.

The NGPN is developing 12 monitoring protocols that specify data collection and reporting procedures for our Vital Signs (see Chapter 5). In the following sections, we present three general approaches these protocols will use for selecting monitoring sites within each park: (1) probability sampling of the target population; (2) use of index sites; and (3) measurement of the entire population (census). We summarize how we will use these three approaches to support defensible inference about NGPN natural resources. Later in the chapter we describe the planned schedules for revisiting NGPN monitoring sites over time and discuss how we will integrate monitoring for multiple Vital Signs to maximize our data collection efficiency and ability to synthesize data.

Probability Sampling in NGPN Monitoring

The NGPN will use probability sampling for the Plant Communities and Land Birds protocols, and for some potential components of the Water Quality, Exotic Plant Early Detection, and Prairie Dogs protocols. We define a sample frame (the collection of all potential sampling units, usually individual sites) covering the target population (Figure 4-1), specify the rules that define probabilities of selection for each potential sample, and select a sample of sites from the sample frame based on a random draw or process (Cochran 1977; Särndal et al. 1992). Probability sampling allows direct statistical inference about the entire population based on data from a sample of the population. Unlike other sampling approaches, probability sampling allows design-based inference based entirely on the specified rules of probability used to generate a sample and on observed values for the sampled units, without any assumptions about the underlying population. In contrast, model-based inference uses a statistical model to estimate characteristics of the target population (Särndal et al. 1992). The accuracy of the resulting estimates depends on the accuracy of the underlying model; however, by leveraging the additional information provided by the model, this inference can produce more precise estimates of parameters of interest than design-based inference. Although model-based inference can be used in all situations, the number of assumptions needed with a model-based approach is reduced when probability sampling is used to select monitoring sites. We therefore use probability sampling when our objective is to make inference about park-wide status and trends based on data from a subset of sites in the park, and when, due to spatial variation within a park, we cannot use data from one or two index sites to make reliable conclusions about park-wide conditions.

Target Populations, Sample Frames, and Sample Selection

The sample frame for NGPN protocols using probability sampling is produced by dividing the target population into a set of discrete units (e.g., a grid of rectangles for terrestrial sampling, or linear segments for streams). If our target population and the actual sample population are mismatched, our statistical inference will apply only to the latter; therefore, we carefully define our target population for each protocol and choose a sample frame that overlaps this population as completely as possible.

This process often requires excluding some portions of each park from the target population for logistical reasons. The sample frame for the Plant Communities protocol excludes areas that cannot be sampled safely, such as steep slopes and cliffs; therefore, our statistical inference does not apply to these areas. Areas in or within 25 m of campgrounds, lawns, buildings, and other administrative areas, and areas within a narrow buffer along park boundaries, roads, and railroads are excluded not because of logistics, but because we cannot afford to assess changes precisely in these areas as well as in the rest of each park. Instead, our limited sampling effort is focused to obtain adequate information on vegetation status and trend in areas of each park where maintaining or restoring native communities is a priority for park mangers. Similarly, because of the expense involved in sampling water quality, monitoring all types of water bodies (permanent or ephemeral, river, stream, spring, or pond) is not feasible, either with probability sampling or an index-site approach. Instead, NPGN resource managers and I&M core staff are prioritizing water bodies within each park to focus monitoring on top priorities.

Overlap of our sampled and target populations must be considered both spatially and temporally. If daily or within-season temporal variation is high, visiting a monitoring site only once during the sampling window may not adequately represent conditions during the time interval of interest. To address this, some NGPN sampling designs incorporate probability-based sampling spatially and repeated regular (systematic) sampling across the temporal window of interest (e.g., by visiting a water quality sampling site every week or by using a continuous monitor during the summer). In other cases, such as with herbaceous vegetation, temporal variability within our sampling window is much lower than spatial variability across the target population, and our statistical efficiency is increased by spending our effort visiting more sites rather than revisiting sites within a year.

Table 4-1. Sampling designs for monitoring protocols to be developed by the NGPN.

Protocol	Sampling Situation	Target Population	Sample Frame	Revisit Design	Rationale for Design
Air Quality	Index sites, with park-wide and regional interpolation	Park-wide surface air and deposition	n/a	[1-0]	Due to expense, most data will come from existing stations, with near-continuous monitoring. When resources permit, additional probability-based or nonprobabilistic sampling can help determine within-park variation (e.g., Burley and Ray 2007) and the adequacy of regional interpolations from model-based inference.
Weather and Climate	Index sites, with regional and possibly within-park interpolation	Entire park	n/a	[1-0]	Due to high expense and siting requirements, index sites are required. Nearly all data will come from existing stations, either with near-continuous monitoring or daily records throughout the year. At the largest Network parks (BADL and THRO), additional probability-based or non-probabilistic sampling could be used to examine accuracy of model-based inference from index sites.
Stream and River Channel Characteristics	Census	Reach of stream or river in park for channel mapping; high-priority cultural sites for park monitoring	n/a	TBD: Single [1-9] panel for channel location; [1-0] for monitoring by parks and U.S. Army Corps of Engineers	Mapping of channel location will be in collaboration with land cover monitoring but may use higher resolution National Agriculture Imagery Program (NAIP) imagery if available for Network parks.
Cave Water and Meteorology					
entrance climate/airflow	Census with low measurement error	Natural entrances of Wind Cave and Jewel Cave	n/a	[1-0]	The caves have one or two natural entrances; continuous monitors can be used to census airflow conditions, temperature, and moisture content.
interior temperature and water quality	Index sites or probabilistic sampling of accessible areas	Accessible areas of the caves	TBD	[1-0]	Sampling away from normal travel routes is expensive; cave features are damaged by frequent human travel. Frequent monitoring is desired to detect water contamination, and use of automated temperature probes allows year-long monitoring.

Table 4-1. Sampling designs for monitoring protocols to be developed by the NGPN (continued).

Protocol	Sampling Situation	Target Population	Sample Frame	Revisit Design	Rationale for Design
Surface and Groundwater Hydrology	Index sites	Reach of stream or river in park; groundwater within park	n/a	[1-0]	Existing gages monitor continuous discharge or yearly maximum height. One station can adequately monitor flow in a reach unless the station is poorly placed or there are significant inputs/withdrawals elsewhere in the park. Groundwater monitoring is limited to available wells.
Water Quality	Index sites, possibly combined with probability sampling	Reach of stream or river in park; springs and groundwater within park	TBD	TBD; [1-0] for some sites	Index sites will be monitored with automated monitors throughout the ice-free season to capture diurnal and seasonal variability. Additional sites may be monitored with a probability design.
Exotic Plant Early Detection	TBD	TBD	TBD	TBD; infrequent visits	Monitoring will incorporate observations of priority species by NGPN staff, possibly combined with some probability surveys.
Plant Communities					
intensive (20 x 50 m) plots	Probability sampling: Generalized Random Tessellation Stratified design (GRTS)	Entire park excluding developed areas and those that cannot be sampled safely	Grid	[2-3] (five panels) in most parks; [2-8] at Badlands and Theodore Roosevelt NPs	Spatial variation is high; inference to park-wide population is desired. Year-to-year variation is high; a [2-3] panel design helps to separate spatial from temporal variability while meeting the Northern Great Plains Fire Ecology Program's (FireEP) needs for relatively short intervals between samples. A longer revisit interval at the two largest and most spatially variable parks allows more sites to be monitored over time.
extensive (10-m radius) tree and fuel plots	Probability sampling (GRTS)	Entire park in Black Hills; floodplain areas of other selected parks	Grid	Single [1-4] panel in each park	Yearly variation is low, and longer term changes are slow except after disturbances.
Land Birds	Probability sampling (GRTS) with high measurement error (incomplete detectability)	Entire park or focal communities (e.g., grasslands) excluding developed areas and those that cannot be sampled safely	Grid	Probably [1-0]	Target population to be determined. Estimation of density, occupancy, or community metrics must account for incomplete detectability of individuals and species during each survey. Due to potential high yearly variation, frequent measurements may be needed to separate short-term variation from long-term trends.

Table 4-1. Sampling designs for monitoring protocols to be developed by the NGPN (continued).

Protocol	Sampling Situation	Target Population	Sample Frame	Revisit Design	Rationale for Design
Prairie Dogs					
colony area	Census with measurement error	Park-wide	n/a	Probably [1-0]	With remote sensing and/or ground mapping, each colony can be censused annually; ground-based mapping can be used to correct/calibrate remotely sensed estimates. Yearly variation may be high.
density	Census or probability sampling with incomplete detectability	All prairie dog towns in SCBL and DETO	TBD	Probably [1-0]	At SCBL and perhaps DETO, colonies may be censused or sampled probabilistically. Incomplete detectability is a major source of measurement error.
Landscape Pattern and Dynamics					
land cover	Census with/without measurement error	Entire park	n/a	Single [1-4] or [1-9] panel	A census is possible. Depending on the parameters, measurement error may be low.
management treatments and disturbances	Census with/without measurement error	Entire park	n/a	[1-0]	Prescribed burns, wild fires, other fuel treatments, herbicide treatments, etc., will be mapped annually.
Soundscape	Index sites in management/acoustical zones, possibly with modeling of sound levels over broader areas within parks	Index sites	n/a	Probably single [1-5] panel	Due to expense, the Network can afford to sample only a few high-priority sites per park; however, supplemental monitoring and development of predictive models may allow broader statistical inference. Year-to-year changes are expected to be low; supplemental park observations will detect major new sources in sound levels between monitoring visits.

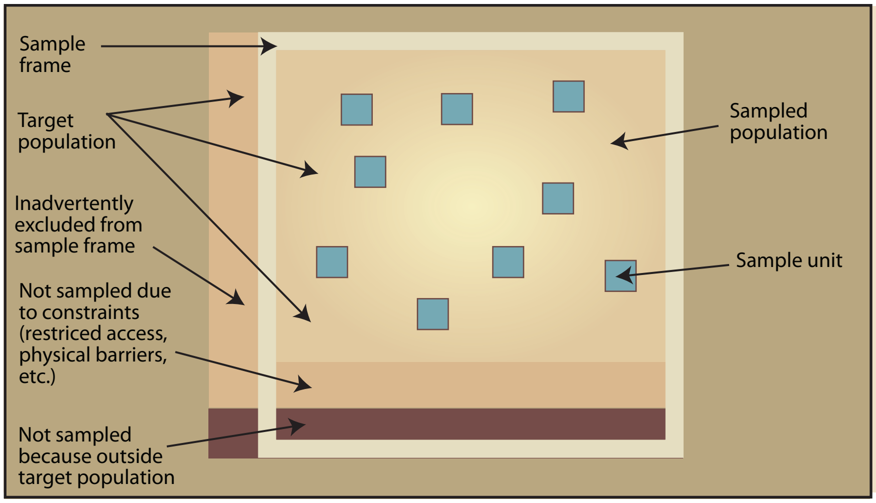


Figure 4-1. Target population, sample frame, and sampled population. Source: NPS 2008*b*.

In protocols using probability sampling, our default approach for selecting samples is the Generalized Random Tessellation Stratified (GRTS) design (Stevens 1997; Stevens and Olson 2004), which is becoming widely used in ecology and has user-friendly tools available for generating samples (e.g., Theobald et al. 2007; Kincaid 2008). This design produces samples that are more spatially balanced (i.e., more evenly distributed across the area of interest; Figure 4-2) than those from simple random sampling, thereby supporting more precise estimates for a fixed sample size.

The GRTS approach also provides some flexibility to adapt to changes in funding, objectives, and even the target population of interest. In selecting a GRTS sample, we generate more samples than we expect to use. Any subset of the list is a spatially balanced sample. If funding increases or decreases in the future, we can increase or decrease our sample size without compromising the spatial balance or statistical validity of the sample. For example, any additional sites from our original oversample are still part of the same GRTS draw, and data from both original and added sets of sites can be analyzed together. The inclusion probabilities for sampled units are known even when such adjustments are made, maintaining our ability to do valid design-based analyses. For example, GIS layers used to select monitoring sites in the Plant Communities protocol do not adequately and accurately map many cliffs and steep slopes, which are outside the target population. Although our sample frame includes these sites, they can be rejected when we first visit them in the field and replaced with the next site in the oversample without compromising the spatial balance of our sample. Conversely, our sample frame at some parks includes areas that may become part the future target population (e.g., inholdings, or areas currently in a river that may change its channel location over time). We can include these areas in the original GRTS draw and treat any sites selected in these areas as dormant samples for future monitoring (T. Philippi, NPS National I&M Program, Fort Collins, CO, pers. comm., 18 November 2008).

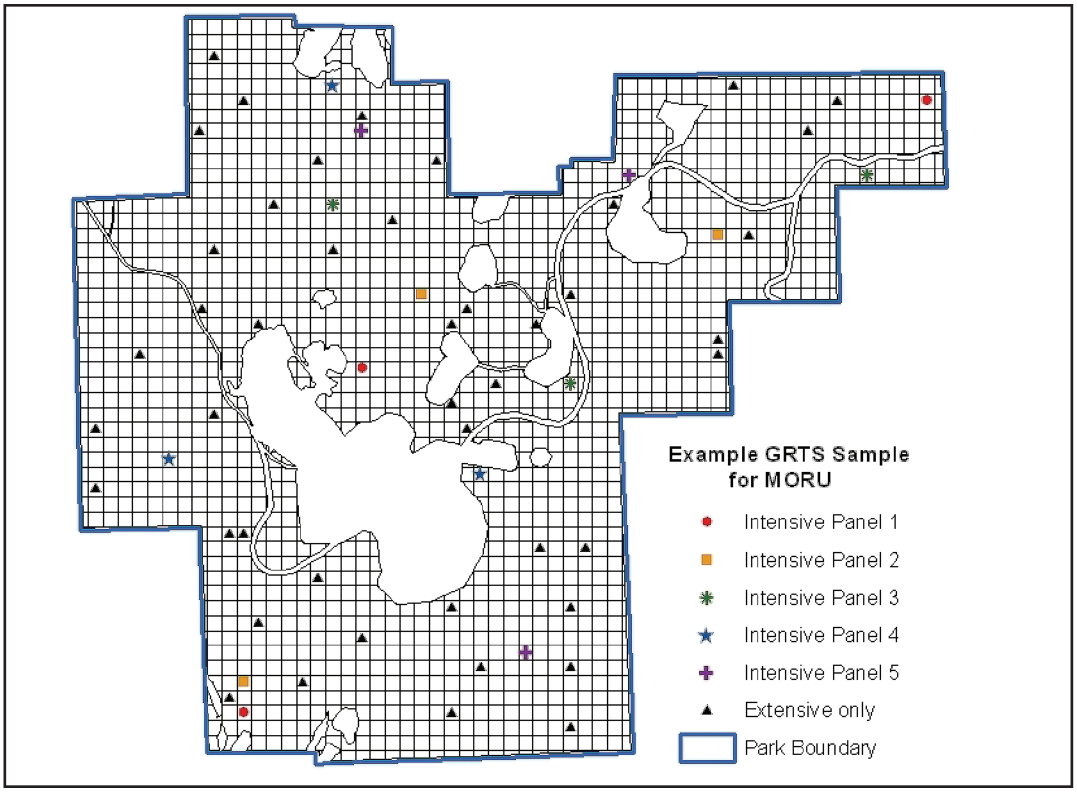


Figure 4-2. Example GRTS design for Plant Communities protocol at Mount Rushmore NMEM.

Herbaceous and woody composition and structure, as well as dead and down woody fuels, will be measured at 15 intensive plots grouped into five panels; each will be visited 2 consecutive years in each 5-year period. Additional data for trees, tall shrubs, and dead and down woody fuels will be collected from a single panel of extensive plots visited once every 5 years. Grid squares are the sample frame from which plots are selected. Other areas outlined in white are roads, developed areas, and rocky/cliff areas excluded from the sample frame.

To maintain flexibility, some common sampling design tools must be used cautiously. A primary example is the use of stratification, which divides a park into two or more non-overlapping subpopulations (strata) that are then sampled independently. If we allocate effort among strata disproportionate to their areas to obtain higher sampling effort in high-interest subpopulations, we eliminate our flexibility for post-stratifying as sites change over time (e.g., as some grassland sites turn into forests), even though our original strata boundaries no longer divide distinct subpopulations. Similarly, we lose the ability to combine sites from different strata during analysis. Therefore, stratification will be used in limited cases and only when other factors may outweigh this loss of flexibility. For example, the Plant Communities protocol will stratify only if (a) areas of high interest exist that can be defined based on semi-permanent features; (b) higher sampling intensity is needed for these areas than would be obtained by sampling them proportional to their size; (c) a spatially balanced sample within these areas is required and cannot be achieved except by stratifying and selecting GRTS samples separately for each stratum; and (d) these needs outweigh the loss of flexibility caused by stratifying. These criteria are met for lowland floodplain areas in several NGPN parks, so stratifying uplands and lowlands is justified for the Plant Communities protocol.

Sources of Variability and Error

In probability sampling, our estimates of status and trend for the target population will differ from the true values due to sampling error, the variation caused by measuring only a subset of the target population. Imprecision in our estimates due to sampling error depends on the number of sites we sample versus the magnitude of spatial variation in the population. Moreover, even with large sample sizes, more than a decade might be required to detect a trend in the population if year-to-year variation is high. Determining the number of sample sites and an appropriate revisit design requires good estimates of year-to-year and spatial variation. Although existing data and data from pilot studies can help assess such variation, good estimates of these variance components may not be available without many years of monitoring. As data accumulate we will need to reassess whether our sampling intensity for a protocol is insufficient or higher than needed to meet our objectives.

We also need to address potential sources of measurement errors, which are random or systematic deviations of the measurement recorded at a site from the true value at sampling time. For example, our on-the-ground surveys of land birds may not detect every individual or species present in a sample unit; therefore, we must structure data collection to match assumptions of statistical models that estimate detectability (e.g., MacKenzie et al. 2006) to produce estimates that account for potential changes in detection probability across time. Other systematic biases caused by variability in observers, equipment, or other factors also must be avoided. For example, our standard operating procedures for a protocol will provide detailed guidelines for calibrating measurement devices (e.g., water quality probes) to ensure consistency of laboratory-based analyses of samples collected in the field and to minimize application variation among field personnel.

Monitoring at Index Sites

For many NGPN protocols, we cannot afford to select a probability sample of numerous sites in a park, or we may not need a probability sample to meet monitoring objectives. Instead, we obtain monitoring data from one or a few index sites per park, sites that may be logistically feasible to monitor with expensive equipment or that are of high management interest. However, statistical inference about broader park-wide trends cannot be made based on data from these index sites without developing a statistical model (Olsen et al. 1999), such as a geostatistical model that interpolates weather or air quality data to produce estimates across a landscape. Usually we simply accept that our statistical inference applies only to the sites we sampled. For protocols using index sites, this limitation is outweighed by the expected value of the information for understanding changes in important park resources, drivers, and stressors. In many cases, monitoring of index sites can produce valuable information for detecting changes in Vital Signs over time and for examining how such changes may be affecting other Vital Signs (Stoddard et al. 1998; Urquhart et al. 1998; Mau-Crimmins et al. 2005).

For the Air Quality, Weather and Climate, and Surface and Groundwater Hydrology protocols, monitoring requires easy-to-access sites and uses expensive equipment with high maintenance costs. Because we usually cannot afford to establish and operate new monitoring sites for these protocols, the NGPN must rely mainly on existing monitoring of index sites by parks, USGS, NPS Air Resources Division (ARD), and other entities. With some exceptions, adding additional monitoring sites for these protocols is a low priority because major changes in air quality, weather patterns, stream/river flows, and groundwater levels are likely to occur at regional rather than within-park scales for most Network parks.

For the Soundscape protocol and for portions of the Cave Water and Meteorology and Water Quality protocols, automated equipment will be used at index sites of high management interest. In some cases, changes at such index sites (e.g., increases in anthropogenic noise at a backcountry area of Badlands NP) would be of high concern regardless of other conditions in the park. In addition, monitoring at index sites may detect changes affecting a larger portion of a park. Water quality monitoring data will be collected with automated equipment at index sites where a stream enters a park, where tributaries enter a river, or where access to the river is feasible (e.g., bridges). These sites may not be representative of all portions of the water body within a park and do not support statistical inference beyond individual sites, yet such monitoring can warn managers of changes likely to be affecting at least some stretch of the stream or river downstream of the index site.

Measurement of the Entire Target Population

For components of several protocols (Stream and River Channel Characteristics, Cave Water and Meteorology, Prairie Dogs, and Landscape Pattern and Dynamics), we will collect measurements throughout each park or site where the associated Vital Signs are relevant. When measurement error is low, we do not need statistical inference to assess changes in the population; we have directly measured these changes for the entire population. However, we still may use a model to estimate the long-term trend in the population (for example, with linear or nonparametric regression). In other cases, our data collection methods may have significant measurement error (e.g., mapping of active prairie dog areas using remote imagery), resulting in a need to collect supplemental data and/or develop a model that allows us to correct bias.

Revisit Designs

The revisit design specifies the schedule for visiting and measuring sample units (sites) across years (McDonald 2003). The NGPN generally will use one of three revisit designs:

- The simplest revisit design consists of a single panel visited every year (a panel is a group of sites with the same revisit schedule). This design is denoted as [1-0], indicating a single panel visited every year with 0 years between visits (McDonald 2003). For a fixed effort, this design covers many fewer sites than alternatives, limiting its ability to estimate status precisely when spatial variation is high. However, for a fixed number of sites, this is the most effective design for detecting a consistent trend, particularly when year-to-year variation is high. In most Network protocols focusing on index sites, monitoring will occur every year (and, with automated monitoring, nearly continuously throughout a portion of each year).
- When a Vital Sign shows little variation from year to year, collecting data every year is not a wise use of our limited funding; instead, sampling a single panel every few years is sufficient. For example, for monitoring tree densities in the Black Hills and in floodplain woodlands of selected parks, collecting data once every 5 years ([1-4][1] revisit schedule) allows us to detect trends and assess major changes that may have occurred since the last visit.
- When annual and spatial variability is high, yearly data are needed from each park and from numerous sites per park (e.g., for monitoring herbaceous vegetation composition). In a serially alternating design, a subset of the panels (and sampled sites) is visited each year (e.g., Figure 4-3). For a fixed effort, this allows us to monitor many more sites than if sites were visited every year, providing more precise estimates of status and higher flexibility for looking at subpopulations of interest. Sampling each site less frequently also may reduce trampling and other sampling impacts (Urquhart et al. 1998). A properly structured serially alternating design with overlapping panels across years sacrifices little power for detecting park-wide trends compared to always-revisit designs (Urquhart and Kincaid 1999).

Panel / Year	1	2	3	4	5	6	7	8	9	10
1	x	x	0	0	0	x	x	0	0	0
2	0	x	x	0	0	0	x	x	0	0
3	0	0	x	x	0	0	0	x	x	0
4	0	0	0	x	x	0	0	0	x	x
5	x	0	0	0	x	x	0	0	0	x

Figure 4-3. Revisit design [2-3] for intensive vegetation monitoring sites in most NGPN parks.

This design has five panels; 10 years of sampling are shown. The sites in a panel are measured 2 of every 5 years; 0 = no sites from the panel sampled in that year; x = number of sites. For example, for non-riparian areas of Wind Cave NP, x = 7 sites: 14 sites (two panels) are sampled each year, and 35 total sites are monitored.

Integration of Measurements for Multiple Vital Signs

To maximize efficient use of our limited funding, when possible we will co-locate monitoring sites for multiple Vital Signs and coordinate field visits for different Vital Signs. Information from co-located or co-visited Vital Signs may also provide a more integrated assessment of ecological condition and in some cases, insight into underlying causes of change. The GRTS approach used by the NGPN and most NPS I&M Networks facilitates co-location and co-visitation by allowing sampling for one set of attributes to be nested within sampling for a related set of different attributes. For example, at Black Hills parks, vegetation monitoring will include a larger number of plots park-wide in which trees, tall shrubs, and dead/down woody fuels are measured every 5 years, and a smaller number of plots in which more intensive vegetation measurements (point-intercept and nested-frequency sampling) will be collected on a [2-3] revisit design. The intensive plots will be a spatially balanced, nested subset of the extensive woody plots, which will allow integrated analysis of both data sets. Data from park-wide mapping of land cover, natural disturbances (e.g., insect outbreaks), and management treatments (prescribed burns, exotic-plant treatments) will be used to help explain changes at these individual vegetation sampling plots over time.

Similarly, for monitoring NGPN water quality Vital Signs, sites where we measure contaminants and microorganisms will be a subset of the sites used for measuring core water quality parameters. Visits to the water quality sites will be timed so that multiple Vital Signs are measured at each visit by the same crew, or so that field samples are collected when automated monitoring equipment is visited for maintenance and data retrieval. When possible, water quality monitoring will be co-located with stream gages to facilitate examination of core parameters and other attributes in the context of available flow data. Other opportunities for integration will be examined as protocols are developed.

Chapter 5
Sampling Protocols

Sampling protocols are the specific recipes for how the NGPN will conduct monitoring. As described by Oakley et al. (2003):

> Monitoring protocols are detailed study plans that explain how data are to be collected, managed, analyzed, and reported, and are a key component of quality assurance for natural resource monitoring programs. Protocols are necessary to ensure that changes detected by monitoring actually are occurring in nature and not simply a result of measurements being taken by different people or in slightly different ways. A good monitoring protocol will include extensive testing and evaluation of the effectiveness of the procedures before they are accepted for long-term monitoring.

This chapter specifies the protocols we are developing, summarizes our protocol development process, describes the content of protocols, and presents our monitoring objectives for each protocol under development.

NGPN Protocol Overview

Currently, the Network plans to develop 12 protocols over the next 3 to 5 years covering 23 Vital Signs (Table 5-1). We will develop protocols covering all Vital Signs monitoring implemented mostly or partially through I&M funding, including the Plant Communities and Water Quality protocols, which are the Network's top priorities. In addition, we will develop protocols focusing on data access, analysis, and reporting for some Vital Signs that provide critical information for interpreting changes in other Vital Signs (e.g., Weather and Climate), even though the data are collected by other agencies or by parks without I&M funding. Chapter 9 summarizes our schedule for development of these 12 protocols. Two other protocols covering two Vital Signs (Viewscape and Night Sky) will be addressed in the future if resources permit. Protocols will not be developed for other Vital Signs monitored primarily by parks or other agencies without significant I&M involvement.

In most cases, there is not a 1:1 relationship between Vital Signs and protocols. Rather, a single protocol often covers multiple Vital Signs, and data relevant to a Vital Sign may come from more than one protocol. This organization reflects our need for efficiency and integration both in protocol development and in field sampling. For example, sampling and data analysis for the Upland Plant Communities and Riparian Lowland Plant Communities Vital Signs share many features and Standard Operating Procedures (SOPs), and are most efficiency addressed in a single protocol. Crews collecting vegetation composition data will also sample fuel loads in some areas; therefore, this protocol also partially addresses the Fire and Fuel Dynamics Vital Sign. In turn, the latter Vital Sign also is monitored partially by the Northern Great Plains Fire Ecology Program's (FireEP) and parks' mapping of burned areas. Similarly, as discussed in Chapter 4, sampling sites for multiple surface water quality Vital Signs are co-located and co-visited as part of a unified Water Quality protocol.

Protocol Development Process

Protocols are tailored to address specific, realistic monitoring objectives. First, NGPN I&M core staff, park staff, and collaborators meet to identify data needed by parks to manage the resource in question. The group identifies a short list of candidate monitoring objectives and questions. Subsequent discussions focus on the most important objectives, which guide development of the protocol. The process is iterative; objectives

Ponderosa pine forest at Mount Rushmore National Memorial

are refined as we develop the protocol. An important NGPN step in refining objectives is continued development of conceptual models focusing on the Vital Signs to be monitored by a protocol. These models help us prioritize specific measurements that may be most useful for detecting changes of concern. Conceptual models help us understand relationships among Vital Signs, possibly suggesting ways to integrate monitoring and hypotheses in data analyses to maximize our understanding of changes in park resources.

Subsequent protocol development requires careful selection and testing of methods, including sampling designs. Throughout this process, the NGPN coordinates its efforts with the national I&M Program, other I&M Networks, and other agencies to avoid unnecessary duplication of protocol development efforts and to build upon existing work. We usually modify an existing protocol or take pieces from multiple protocols to produce a recipe that best meets our specific objectives and is appropriate for our ecological conditions. We also use other protocols and research to determine key methodological uncertainties to be addressed through field testing. Protocol development may require a multiyear effort to develop and test sampling procedures and to draft SOPs. Finalized protocol documents are then sent through informal internal and formal external peer review. Following reviews and revision, the approved protocol is accepted for full implementation, and monitoring commences.

In many cases, protocol development requires specialized technical expertise and access to equipment or resources from other NPS offices or external collaborators. Chapter 8 summarizes collaborations that take advantage of diverse agency, academic, and other professional expertise to leverage and augment Network resources. For each protocol, however, the NGPN staff ultimately is responsible for making sure the objectives and final protocol meet the needs of Network parks, are realistic and efficient, and take advantage of opportunities to integrate monitoring among multiple protocols. That is, when we develop protocols in partnerships with other collaborators, we must ensure that the resulting protocol meets the Network's needs.

A Protocol Development Summary (PDS) is required for each monitoring protocol planned for development and implementation by the NGPN monitoring program (Appendix D). The PDS is a short document that identifies the Vital Signs monitored via the protocol, summarizes the justification for the protocol, and describes specific issues and questions being addressed. The PDS lists specific monitoring objectives, describes the proposed methodological approach, and presents other details.

Protocol Content and Format

Monitoring protocols follow the document standards described in Oakley et al. (2003). This guideline specifies protocol format and content and emphasizes a modular structure that facilitates information access while supporting a well-documented history of change and revision. Monitoring protocols consist of several discrete sections:

- The protocol narrative provides the background and rationale for the protocol. As part of this background, the protocol summarizes background research and relevant previous studies. The narrative describes specific measurable objectives and monitoring questions and identifies how the data to be collected will address these questions; describes the sampling design, field methods, data analysis and reporting, staffing requirements, training procedures, and operational requirements; and summarizes the design phase of the protocol development and documents key methodological decisions. By documenting all steps in protocol development, the narrative helps ensure that future proposed refinement of the protocol builds on previous trials or comparisons (Oakley et al. 2003). Narratives also provide a listing and brief summary of all SOPs.
- The narrative is followed by a series of SOPs that explain step-by-step how each procedure will be accomplished. At a minimum, separate SOPs address pre-sampling training requirements, equipment operations, field and laboratory data collection methods, data management, data analysis, reporting, and any activities required at the end of a field season. One SOP identifies when and how revisions to the protocol are undertaken. As stand-alone documents, individual SOPs are easily updated. A revision log for each SOP identifies any changes that are implemented, by whom, when, and why.
- Complete monitoring protocols identify supporting materials critical to development and implementation (Oakley et al. 2003). The final elements or sections in a typical protocol include literature cited and attachments such as appendices, data tables, handbooks, and other supporting information, which include any materials developed or acquired during protocol development, such as databases, reports, maps, geospatial information, species lists, and analysis tools tested. Supporting materials also document any decisions resulting from such testing and exploratory analyses.

Table 5-1. Protocols being developed during the next 1 to 5 years by the NGPN.

Protocols are listed in approximate order of priority for development, with the exception of protocols applying to a subset of parks (Prairie Dogs; Cave Water and Meteorology). Where there are multiple Vital Signs for a protocol there is not necessarily one to one relationships with monitoring objectives.

Protocol	Vital Signs	Monitoring Objectives	Justification	Parks
Plant Communities	Riparian Lowland Plant Communities Upland Plant Communities Fire and Fuel Dynamics	1. In all NGPN parks except MNRR and NIOB, determine park-wide status and long-term trends in vegetation species composition (e.g., non-native vs. native, forb vs. graminoid vs. shrub) and structure (e.g., cover, height) of herbaceous and shrub species. 2. Determine park-wide status (at 5-yr intervals) and long-term trends of tree density by species, height class, and diameter class, and trends in forest fuel loads by fuels classes, in Black Hills parks (DETO, JECA, MORU, WICA). 3. Determine status (at 5-yr intervals) and long-term trends of tree density by species, height class, and diameter class in lowland areas near perennial streams/rivers in selected parks (DETO, FOLA, KNRI, SCBL, THRO). 4. Determine trends in plant species composition and community structure in selected areas of NGPN large-river parks (MNRR and NIOB). 5. Improve our understanding of the effects of external drivers and management actions on plant species composition and vegetation structure by correlating changes in vegetation composition and structure with changes in climate, landscape patterns, atmospheric chemical composition, fire, and invasive plant control.	Identified as a high priority throughout the NGPN. Vegetation composition and structure affect faunal abundance, distribution, and composition; influence local microclimate (e.g., Breshears and Barnes 1999), fire regimes (D'Antonio and Vitousek 1992), and nutrient flows into streams (Naiman et al. 2005); and are part of the scenery enjoyed by visitors. Plant community composition is sensitive to most stressors affecting Network parks, including external stressors such as exotic species, habitat fragmentation, river flow management, climate change, atmospheric nutrient deposition, pollution, and fire suppression, as well as management activities such as ungulate management, prescribed fire programs, visitor use, and exotic species control (Symstad 2004). Changes in cover, species occurrence, and structure (e.g., increasing exotic species cover, lack of tree regeneration in riparian forests) at fine scales may indicate or precede broader changes in the composition and productivity of park ecosystems. This protocol can be implemented cost effectively through collaboration with FireEP. The combined crew will collect data on fuel loads in intensive monitoring plots. Monitoring tree densities and dead and down fuels will also help the Network and FireEP examine fuel loads and risk of high-severity fires in Black Hills forests.	All

Table 5-1. Protocols being developed during the next 1 to 5 years by the NGPN (continued).

Protocol	Vital Signs	Monitoring Objectives	Justification	Parks
Water Quality	Surface Water Chemistry Aquatic Contaminants Aquatic Microorganisms Aquatic Macro-invertebrates	1. In all NGPN parks with surface water, determine status and trends in temperature, pH, dissolved oxygen, and specific conductivity at selected locations in perennial streams/rivers and springs. 2. At selected locations in NGPN perennial rivers and streams, determine status and trends in diversity, abundance, and community metrics of aquatic macroinvertebrates. 3. Determine status and trends in high-priority contaminants and aquatic microorganisms in selected rivers, streams, and springs of NGPN parks. 4. Determine correlations between trends in water quality parameters vs. changes in discharge, stream channel characteristics, weather/climate, human activities and developments, and watershed land cover.	To help meet standards of the Clean Water Act, funding is granted to I&M Networks specifically for water quality monitoring. Water quality is a top monitoring priority by parks for tracking park ecological health, measuring compliance with federal and state laws and standards, and detecting threats to human health. All parks are concerned about effects of dams, agricultural uses, and human developments in surrounding watersheds. Heavy livestock grazing and feedlots may increase erosion, turbidity, nutrient inputs, and bacterial levels (Scrimgeour and Kendall 2003). Herbicides may alter macroinvertebrate abundance and species composition (Lenat 1984). Roads and developments alter runoff, sedimentation, water chemistry, light, and temperature (Trombulak and Frissell 2000). Sampling for these four Vital Signs will be co-located and co-visited by the same personnel. Macroinvertebrates can supplement direct measurements to provide a general indicator of aquatic condition (Rust 2006).	All except FOUS
Exotic Plant Early Detection	Exotic Plant Early Detection	1. Develop and update every 1–5 yr a list of high-priority non-native plant species encroaching on each NGN park unit. 2. Develop and distribute educational materials (e.g., identification and habitats of concern) about these species to parks, other NPS programs, partners, other agencies, and park visitors. 3. Develop and maintain a communication plan and online database for soliciting, storing, reporting, and sharing information about incidental observations of these species by park staff, other NPS program staff, partners, and visitors. 4. Based on qualitative or quantitative prioritization and prediction of habitats most at risk of colonization by targeted species, design and implement field sampling (in collaboration with park staff and volunteers) in each park at 2–5-yr intervals to detect new occurrences of these species.	Controlling invasive plants is a high priority to Network parks (Symstad 2004) and a primary conservation issue globally (Mack et al. 2000), given the potential for the impairment of native ecosystems. Early detection and rapid treatment are the most effective way to control invaders (Hobbs and Humphries 1995; Rejmánek and Pitcairn 2002). The I&M Program can help NPS prevent new establishments by helping parks and the Northern Great Plains Exotic Plant Management Team (EPMT) stay updated on high-risk non-established species, obtaining observations of these species from others on the ground, and conducting additional surveys.	All

Table 5-1. Protocols being developed during the next 1 to 5 years by the NGPN (continued).

Protocol	Vital Signs	Monitoring Objectives	Justification	Parks
Landscape Pattern and Dynamics	Land Cover and Use Fire and Fuel Dynamics Forest Insects and Diseases Treatments of Exotic Infestations Extreme Disturbances	1. Determine patterns and long-term trends in land cover distribution within and adjacent to NGPN park boundaries. 2. Annually update a spatial database for each park describing characteristics of management activities and natural disturbances (>0.5 ha) within park boundaries known or suspected to influence vegetation structure and composition and/or water quality (e.g., treatment summary and/or spatial/temporal extent of prescribed fires, wild fires, invasive plant control, overstory tree mortality from mountain pine beetles, etc.).	Monitoring of land cover and plant communities complement each other, with compositional and finer scale structural changes captured by the latter and larger scale park-wide structural changes captured through this protocol. The type, amount, and arrangement of vegetative structural types are partial indicators of occurrence and abundance of wildlife species that we cannot afford to monitor directly (Vinton and Collins 1997). Fragmentation can widely impact biodiversity and ecosystem function (Saunders et al. 1991); spatial pattern has fundamental effects on landscape ecology (Turner et al. 2001). To assess changes in vegetation composition and land cover, we need to integrate spatial data collected by others for prescribed and wild fires, other fuels treatments, exotic-plant treatments, and forest insects and diseases. This protocol has relevance to most other protocols. Tracking changes in watershed-level landscape composition may help explain or anticipate water quality changes. Because caves are part of a karst landscape, they may be sensitive to changes in surface use and land cover, especially to changes affecting hydrologic connections. We need to document other infrequent disturbance events (e.g., windstorms), which can shape ecosystems (Friedman and Lee 2002; Parsons et al. 2005).	All
Weather and Climate	Weather and Climate	1. Determine daily, monthly, seasonal, and annual descriptive summaries for average temperature, temperature extremes, total precipitation, temporal x amount-class distribution of precipitation events, and wind characteristics from at least one index station in or near each park unit. 2. Provide an internet portal by which parks can access summaries and raw data from these stations. 3. Determine patterns of among-year variability and long-term trends in these weather/climate variables.	This is a fundamental driver of all Network ecosystems (Chapter 2). Trends in temperature and precipitation need to be understood in order to explain trends in other resources; annual climate measures are needed as covariates in trend analysis for many Vital Signs due to high among-year variability. Existing efforts through several regional and national networks of weather/climate stations collect these data; the NPS national I&M Program has provided a portal to access summaries and raw data. Davey et al. (2007) identified gaps in current weather/climate monitoring; the Network is discussing how to address these needs.	All

Table 5-1. Protocols being developed during the next 1 to 5 years by the NGPN (continued).

Protocol	Vital Signs	Monitoring Objectives	Justification	Parks
Surface and Groundwater Hydrology	Surface Water Dynamics Groundwater Dynamics	1. From active USGS flow gages in and near NGPN parks, summarize seasonal and annual trends and variation in discharge, stream/river water level, and peak annual flow. 2. At water quality sampling locations in NGPN streams and rivers, determine discharge at the time of sampling to help interpret water quality data and (for reaches without USGS gages) to examine seasonal and long-term trends in discharge. 3. At existing wells in selected NGPN parks, determine seasonal and annual variations and long-term trends in hydrographs for groundwater levels. 4. Obtain aquifer-level monitoring summaries from other state and regional groundwater monitoring networks to examine impending threats to park groundwater supplies. 5. Determine correlations between trends in stream flows and groundwater dynamics vs. changes in weather/climate, park and watershed landcover changes, and other human activities and developments.	In this semi-arid region, water is often a scarce resource. Dams, irrigation and municipal withdrawals, and groundwater depletion have significantly changed the hydrographs of most NGPN rivers, with large-scale effects on aquatic and riparian ecosystems (Longo and Yoskowitz 2002). In portions of the Network (southern Black Hills, Nebraska, and Wyoming), groundwater sources are increasingly endangered because irrigation water is being withdrawn from aquifers faster than it is being recharged (Luckey et al. 1988; Flores 1995). By summarizing and reporting data from USGS stream gages, park-specific monitoring of well water levels at some parks, and regional monitoring of groundwater levels by Natural Resource Districts and other entities, the Network can help examine changes in river flow and detect impending threats to park groundwater sources.	All
Land Birds	Land Birds	1. Determine changes in breeding-season density of common species, relative abundance and occupancy of less common species, species richness, and other community characteristics in all NGPN parks or in selected habitat types (grasslands, floodplains, and/or Black Hills forests). 2. Determine correlations between avian population/community changes and changes in land cover, vegetation structural stages, landscape composition, and climate. 3. Determine similarity of these park-level trends vs. regional trends estimated by Breeding Bird Surveys and other monitoring efforts.	Land birds are of high interest to park managers and are a species-rich group that parks must conserve and protect. Changes in landbird populations can indicate changes in habitat structure, climate, food supply, nest predation, and landscape changes. In addition, NGPN parks can serve as reference sites for helping interpret regional trends abundance for species of concern and other birds. Of the 100 landbird species in Canada and the U.S. on the Partners in Flight (PIF) Watch List (Rich et al. 2004), ~1/3 occur in Network parks. These species are included on the Watch List because of threats to their habitats, declining populations, small population sizes, or limited distributions. More than half the species on the 2004 PIF North American Land Conservation Plan Stewardship Species List are in Network parks.	All (TBD)

Table 5-1. Protocols being developed during the next 1 to 5 years by the NGPN (continued).

Protocol	Vital Signs	Monitoring Objectives	Justification	Parks
Air Quality	Ozone Wet and Dry Deposition Visibility and Particulate Matter Air Contaminants	1. Collect hourly, daily, or weekly measurements of ozone, wet/dry deposition (nitrogen compounds, mercury, and sulfur compounds), visibility, and particulates at BADL, THRO, and WICA. 2. Supplement NPS Air Resources Division (ARD) and regional monitoring by collecting hourly, daily, or weekly measurements of ozone amounts, nitrogen deposition, and/or mercury deposition at other selected NGPN parks. 3. At the spatial scale of individual parks, sub-regions (e.g., Black Hills), and entire Network, collaborate with ARD to report seasonal and annual descriptive statistics and to determine temporal variability and long-term trends of selected stressors that have the potential to cause large changes in vegetation composition and structure (ozone or nitrogen deposition) or to contaminate aquatic systems (mercury).	Ozone damage, nitrogen fertilization, and mercury inputs may be important stressors of terrestrial and aquatic communities (e.g., Miller 1973). Continued energy developments in Wyoming and North Dakota may increase pollution. Among NGPN units, active monitoring occurs only at the three Class 1 air quality parks. The regional network of stations may not cover some parks adequately. Monitoring with I&M funds may be implemented at AGFO, DETO, NIOB, and/or SCBL depending on results of work during 2008–2010 assessing potential gaps in current monitoring.	BADL, THRO, WICA; TBD (AGFO, DETO, NIOB, or SCBL)
Stream and River Channel Characteristics	Stream and River Channel Characteristics	1. In all parks except JECA and FOUS, determine status and long-term trends in channel profile, substrate composition, and bank characteristics at selected locations in perennial streams/rivers at 5–10-yr intervals. 2. Through aerial imagery, examine changes in location and characteristics (sinuosity, width) of active river channels at 10-yr intervals. 3. At KNRI and FOUS, determine rates of bank erosion in high-concern archeological areas. 4. Correlate and compare changes in channel characteristics with changes in stream/river hydrology, floodplain and watershed land cover, and broader scale changes in channel locations.	Changes in channel morphology affect sediment loads and alter riparian habitats (Gordon et al. 1992). Increased channelization contributes to reduction in active floodplains, reducing or eliminating recruitment of cottonwoods. Reduction in active sediment movements causes loss of nesting habitat for Piping Plovers and Least Terns, and reduction in suitable habitat for pallid sturgeons. Coarse changes in river channel characteristics can be measured inexpensively through aerial imagery. At Knife R. Indian Villages and Fort Union Trading Post NHSs, river erosion threatens archeological sites; park-led monitoring addresses this issue.	All except JECA

Table 5-1. Protocols being developed during the next 1 to 5 years by the NGPN (continued).

Protocol	Vital Signs	Monitoring Objectives	Justification	Parks
Soundscape	Soundscape	1. At selected index locations in each park, determine status (at 1–10-yr intervals) and trends in acoustical metrics such natural ambient sound pressure levels, time above ambient level, and frequency of intervals with only natural sounds, as well as sound-source information (percentage of samples with sounds from anthropogenic and natural sound-source categories). 2. Determine correlations between soundscape changes and changes in visitor numbers, developments, and bird communities.	Sound levels are important to many parks because of the effects on visitor experiences (Gramann 1999). At Badlands NP, 70% of visitors ranked “natural quiet” as very or extremely important (Simmons and Gramann 2001). However, degradation of soundscapes is a concern at most Network parks due to air tours, railroads, etc. For example, MORU is one of the five parks in the nation most threatened by noise pollution (Coalition of National Park Service Retirees 2008). Noise that adversely affects park resources and visitor experience must be prevented or minimized (NPS Director’s Order #47, Dec 2000). To help parks address these issues, data can be collected efficiently with automated equipment, and can help track changes in natural sounds (e.g., Corn et al. 2000). The protocol produced in collaboration with the NPS Natural Sounds Program will be useful throughout NPS.	All
Cave Water and Meteorology	Cave Meteorology Groundwater Dynamics Cave Water Chemistry Aquatic Contaminants	1. Determine seasonal, annual, and long-term changes in the water level of the Madison Aquifer in Wind Cave. 2. Detect changes in selected water quality parameters and contaminants in the aquifer, drip sites, and other water sources below developed areas and selected undeveloped areas of Jewel Cave and Wind Cave. 3. Determine trends in temperature (mean, variation) at selected sites near entrances and interior portions of Jewel Cave and Wind Cave. 4. Determine changes in entrance airflow characteristics (heat, air mass, and water mass exchange; direction and velocity of flow) at natural entrances of Jewel Cave and Wind Cave.	Jewel Cave and Wind Cave are globally significant caves and are the reason for the establishment of their respective parks. Maintaining stable conditions in the caves is a fundamental mission of these parks. Toomey (2006) identified cave climate as the most important attribute to monitor in cave environments. Internal changes in humidity and temperature changes resulting from external climate changes and visitor tours could degrade delicate physical formations (e.g., gypsum strands) deep in the cave (Nepstad and Pisarowicz 1989). Climate change could affect the large winter population of hibernating bats (Choate and Anderson 1997) and the detritus-based food web of the cave (Nepstad and Pisarowicz 1989; Moore 1996). Monitoring cave water quality may allow detection of surface contamination from developed sites or aquifer pollution that would not be captured by surface water sampling. Wind Cave offers direct access to the Madison Aquifer, allowing detection of changes in water level caused by drought or withdrawals.	JECA WICA

Table 5-1. Protocols being developed during the next 1 to 5 years by the NGPN (continued).

Protocol	Vital Signs	Monitoring Objectives	Justification	Parks
Prairie Dogs	Prairie Dogs	1. For black-tailed prairie dogs, determine summer population density, area, and spatial characteristics of active towns annually at Scotts Bluff NM. 2. Determine total area and spatial characteristics of active prairie dog towns annually at Wind Cave NP, Badlands NP, Theodore Roosevelt NP, and Devils Tower NM, and integrate spatial data into the NGPN's landcover database.	Black-tailed prairie dogs are an ecologically dominant species that strongly influences grassland biodiversity, vegetation composition and structure, forage availability, and soils (Miller et al. 2000; Lomolino et al. 2004; Hoogland 2006). The endangered black-footed ferret in WICA and BADL is dependent upon prairie dogs. Prairie dogs may occupy approximately 2% of their historic range (USFWS 2000; Proctor et al. 2006). Prairie dog management is highly controversial (Hoogland 2006; Miller et al. 2007), and managers need data on current status to defend management decisions at the five NGPN parks where prairie dogs occur.	SCBL BADL DETO THRO WICA
Night Sky[a]	*Night Sky*	*1. Determine status and trends in summertime night sky darkness at selected sentinel observation points in or adjacent to each NGPN park at 5–10-yr intervals.* *2. Determine correlations between changes in night lighting and changes in park infrastructure and adjacent developments.*	*Night sky darkness is important to many visitors; potential ecological impacts are of increasing concern (Rich and Longcore 2005). Data can be collected every 5–10 yr and are needed to determine whether the NPS goal of maintaining natural "lightscapes" is being met (NPS 2007b).*	*All*
Viewscape[a]	*Viewscape*	*1. At selected index locations in each park, collect and archive digital images at 1–10-yr intervals.* *2. Characterize status and determine long-term changes in selected characteristics of each viewshed (e.g., amount of viewshed in forest vs. grassland; number and types of human developments visible).* *3. Compare observed changes with those detected park-wide through the Landscape Pattern and Dynamics, Plant Communities, and other protocols.*	*Visitor satisfaction is affected strongly by viewshed characteristics. Repeated photos summarize and help communicate ecological changes (e.g., Klement et al. 2001; Grafe and Horsted 2002), and capture trends in visibility (Pohlman and Maniero 2005).*	*All*

[a]Night Sky and Viewscape protocols will be developed if funding permits once other protocols are implemented.

Chapter 6
Data Management

Data and information are the primary products of ecological monitoring. As part of the Service's efforts to improve park management through greater reliance on scientific knowledge, a primary purpose of the monitoring program is to acquire, organize, and make available natural resource data… A well-designed and well-documented data management system is particularly important for the success of long-term programs where the lifespan of a data set will extend across the careers of many scientists, and numerous changes in technology are to be expected.
—Fancy et al. (2009)

Data management is the framework by which data are acquired, maintained, and made available to our diverse audiences. The central mission of the NPS I&M Program is to provide timely and usable scientific information to park managers about the status and trends of park resources. To meet this challenge, we need an information management system that can effectively produce, maintain and distribute the products of scientific work done in our parks. Data management is a critical element of this system.

Planning for effective data management has been a major focus of the I&M Program at the national, regional, and Network levels. The National I&M Program provides current guidelines and guidance to the 32 I&M Networks (http://science.nature.nps.gov/im/datamgmt/index.cfm). The NGPN data management strategy draws from these guidelines and formalizes them as Network policy. This chapter summarizes major components and aspects of this strategy. The Network's Data Management Plan (DMP) provides more details (Appendix E). More specific strategies are documented in Standard Operating Procedures (SOPs) for monitoring protocols.

Goals and Priorities for NGPN Data Management

Goals of Data Management

Through its data management system, the NGPN seeks to ensure the quality, interpretability, security, longevity, and availability of ecological data and related information resulting from resource inventory and monitoring efforts:

Quality – We will ensure that appropriate quality-assurance measures are taken during all phases of project development, data acquisition, processing, summary and analysis, reporting, and archiving. These measures should reflect current best practices and scientific standards. An important part of quality assurance is to continually encourage careful attitudes and good habits among all staff collecting, handling, and interpreting data.

Interpretability – We will provide sufficient documentation for each data set and any reports and summaries derived from it to ensure users will understand the applicability and limitations of the data. A data set is only useful if it can be understood readily and interpreted in the context of its original scope and intent. Data taken out of context can lead to misinterpretation and bad management decisions. Similarly, data sets that are obscure, complex, or poorly documented can be misused easily.

Security – We will maintain and archive both digital and analog forms of source data in an environment that provides appropriate levels of access to project managers, technicians, park managers, and others. Existing systems for network security and backup will be used and augmented with specific measures aimed at ensuring the long-term security and integrity of our data.

Longevity – We will enhance the longevity of our data set by thorough documentation, by maintaining the data in a widely interpretable format, and by appropriate archival measures. Countless data sets have been lost over time simply because they were not sufficiently documented, organized, or maintained in up-to-date formats (Bingham 2007). The investment required to maintain this longevity almost certainly pays off because the data set is much more likely to be used effectively over a longer period.

Availability – We will ensure that the products of inventory and monitoring efforts are created, documented, and maintained in a manner that is transparent to the potential users of these products. Natural resource information is useful for informing decisions only if it is available to managers at the right time and in a usable form. However, some sensitive information must be maintained securely and with appropriate safeguards.

Data Management Priorities

The highest priority for the NGPN data management program is to produce and curate high-quality, well-documented data originating with the I&M Program, particularly from monitoring of core Vital Signs. Collecting, organizing, and cataloging data collected by others, if such data are applicable to Network's core Vital Signs, is a fundamental part of the I&M mission. As funding and staff time permit, we also strive to help manage data from other current and completed projects that complement our Program objectives. In particular, the I&M Program uses its data management expertise and resources to help Network parks practice good data management practices for park-specific natural resource projects.

Data Stewardship Roles and Responsibilities

Every individual involved in the production, analysis, management, or end use of data from the NGPN I&M Program has data stewardship responsibilities (Table 6-1); each monitoring protocol will describe these responsibilities in greater detail and will document relevant SOPs.

NGPN Data Infrastructure and System Architecture

Infrastructure refers to the network of computers and servers that are the foundation of our information systems. The infrastructure supports these required functions:

- Provides a central repository for master data sets
- Provides controlled subsets of data for local computing
- Provides a means for uploading and downloading data for both NPS and public uses
- Supports desktop and internet applications
- Provides security, stability, and backups

The NGPN relies heavily on NPS national and regional information-technology personnel and resources to maintain its computer infrastructure. The Network has developed procedures to maintain, store, and archive data to ensure that data and related documents are accessible and secure. Content, format, and documentation must be up-to-date so that the data can be easily accessed and properly used. Data must also be physically secure against environmental hazards, catastrophe, and human malice. Most data maintenance will be performed on the Network file server and on NPS-wide servers maintained by the I&M Program. The NGPN data management staff is responsible for ensuring that regular data backups are performed for all Network data. Data and information on Network and NPS servers will be kept current, and all updates will

Table 6-1. Data management roles and responsibilities in the NGPN.

Depending on skill sets, multiple roles may be filled by a single Network staff member.

Role	Primary Responsibilities Related to Data Management
Protocol project leader	Direct operations, including data management requirements, for project
Project crew leader	Supervise crew; communicate with data manager and project leader
Project crew member	Collect, record, enter, and verify data; organize field forms, photos, and other related materials
Resource specialist	Evaluate validity and utility of project data; document, analyze, and publish data and associated information products
Network Data Manager	Ensure program data and information are organized, useful, compliant, safe, and available. Oversee Global Positioning System (GPS) data collection; manage spatial data; prepare maps; perform spatial analyses
Assistant Data Manager	Apply database and programming skills to Network projects; maintain information systems to support data management
Consulting statistician and quantitative ecologist	Determine project objectives and sample design; perform (or guide) and document data analysis and synthesis; prepare reports
Network Coordinator	Coordinate and oversee all Network activities
Park or regional curator	Ensure project results (documents, specimens, photographs, etc.) are cataloged and accessioned into NPS or other repositories
National I&M Program Data Manager	Provide NPS-wide database support and services; provide data management coordination among Networks
End users (managers, scientists, interpreters, public)	Define information needs; interpret information and use it to direct or support decisions

be described in accompanying documentation. Information files will be properly cataloged and maintained on the NGPN website, and the latest versions of primary data will be available in formats that reflect common usages.

Web-based access will be the primary mechanism for accessing data from the NGPN. The NPS National and NGPN I&M offices have developed web-based applications and repositories to store a variety of park natural resource information (Table 6-2).

Table 6-2. Natural resource data provided on NGPN and National I&M websites.

Web Application	Data Available
NPS IRMA	Portal to a variety of NPS information sources; will include NPSpecies, NatureBib and NPS Data Store links
NPSpecies	Database of plant and animal species known or suspected to occur on NPS park units; includes a species keyword search for reference materials (http://science.nature.nps.gov/im/apps/npspp/index.cfm)
NatureBib	Bibliography of park-related natural resource information (http://science.nature.nps.gov/im/apps/nrbib/index.cfm)
NPS Data Store	Park and Network-related metadata and selected datasets (spatial and nonspatial) (http://science.nature.nps.gov/nrdata/)
STORET	Database for physical, chemical, and biological water quality related data for every NPS unit (http://www.epa.gov/storet/dw_home.html)
NPClime	Data and information for real-time weather, historical climate patterns, and climate-station metadata for every NPS unit (http://science.nature.nps.gov/im/inventory/climate/wrcc/index.cfm)
NGPN websites	Through the use of the Network's inter- and intra-net web sites and the use of MS SharePoint, the NGPN will make available reports, summaries, outreach materials, and monitoring data and information for Network projects; tools for data, data downloads, and database templates also will be available (http://science.nature.nps.gov/im/units/ngpn/)

General Data Management Process for Each NGPN Protocol

Database Design Strategies

Although all Network protocols share a similar general data life cycle (Figure 6-1), the details of these data management steps must be tailored to each protocol. The project manager (protocol lead) and the data manager work together to develop conceptual and logical data models of the data life cycle and flow of the data collection process. As part of this process, they need to understand how data are collected (for example, through a visit to a field site) and what steps are involved in data processing.

Understanding relationships among data components is the key to successfully developing and using a database. Data management elements, or principles common to more than one Vital Sign, will be managed in a manner that enhances data integrity and allows for integration of data across the Network. This applies both within a single monitoring protocol and across protocols. Integrated data management for multiple Vital Signs covered by a single protocol will facilitate integrated analysis and reporting. Identifying the types of questions likely to be addressed with data from multiple protocols ensures that data management for these protocols facilitates broader scale analyses.

Acquiring and Processing Data

The types of data handled by the I&M Program fall into three general categories:

1. Program data are produced by projects initiated (funded) by the I&M Program or involve the I&M Program in another manner (e.g., natural resource inventories funded by other sources).

2. Non-program legacy and new data were/are produced by NPS entities without the involvement of the I&M Program (e.g., park or regional projects).

3. Non-program external data are produced by agencies or institutions other than NPS (e.g., weather and air quality data).

Steps in data acquisition and processing vary with these three general data types. For program data, the methods and tools required for the collection of field data (e.g., paper data forms, field computers, automated data loggers, and GPS units) are specified in individual monitoring protocols and study plans. Field crew members must closely follow the SOPs in the project protocol. Techniques for handling data acquired from non-program sources, such as data downloaded from other agencies, will be specified in individual monitoring protocols.

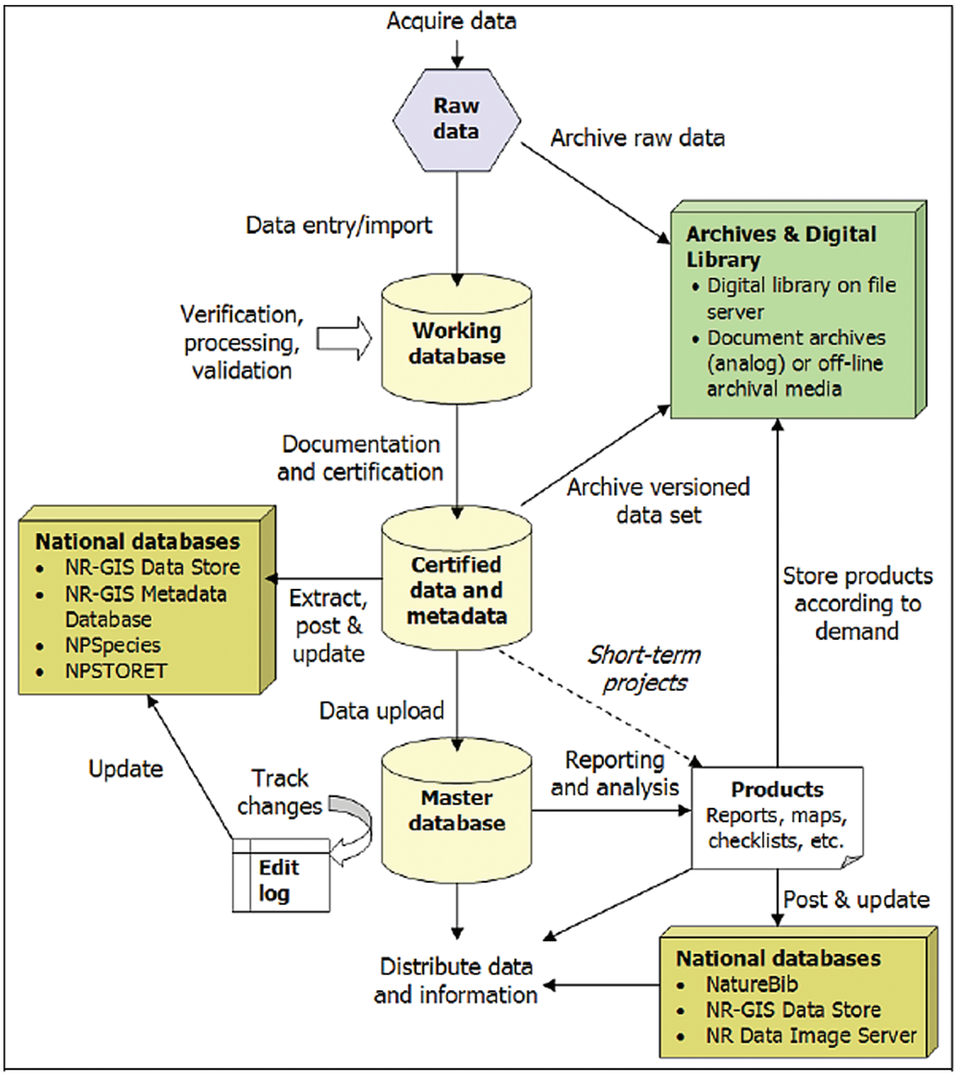


Figure 6-1. Diagram of the typical project data life cycle.

Ensuring Data Quality
High-quality data and information are vital to the credibility and success of the I&M Program. All NGPN staff help ensure that products conform to data-quality standards, and each I&M protocol includes specific quality assurance/quality control (QA/QC) procedures. These procedures include protocol-specific practices as well as some general QA/QC procedures applicable to most or all protocols.

All protocols involving data collection in the field will specify procedures for standardizing field data sheets with descriptive data dictionaries, training field crew members, maintaining and calibrating equipment, effectively using handheld computers and data loggers, and handling data in the field. These protocols will specify the use of database features to minimize transcription errors (e.g., validation rules, range limits, pick lists, and routines to import data from data loggers). All protocols will specify procedures for verifying and validating data; these will include error-checking routines that are automated in NGPN databases.

Quality-assurance methods are established at the inception of any project and continue through all stages of the project. The final step in project quality assurance is the preparation of summary documentation that assesses the overall quality of the data. The project manager will compose a statement of data quality to be incorporated into the formal metadata. Metadata for each data set will also include information on quality assurance procedures specific to the project.

Data Documentation
Appropriate use and interpretation of a data set and information derived from it requires documentation of data sets, data sources, and data collection methodology. At a minimum, all data managed by the Network will require documentation of the project, formal metadata compliant with Federal Geographic Data Committee standards, and data dictionaries and Entity Relationship Diagrams for all tabular databases. Data documentation will be available via the NGPN website as well as the National I&M Program's NPS Data Store.

Data Analysis and Reporting
Providing meaningful and useful information to park managers and other audiences is a cornerstone of the NGPN data management program. Each monitoring protocol establishes requirements, including schedules, for data analysis and reporting. Based on such requirements, the associated databases for the protocols will include functions to summarize and report directly from the database and will allow output in formats that can be easily imported to other analysis software programs. In addition to tabular and charted summaries, summaries usually will include maps of natural resource data and GIS analysis products to communicate spatial locations, relationships, and geospatial model results. Chapter 7 provides an overview of the NGPN's analysis and reporting strategies.

Data Dissemination
The NGPN data-dissemination strategy seeks to ensure that:

- Data are easily discoverable and obtainable
- Data are not released until quality-assurance procedures have been completed, unless release is necessary in response to a Freedom of Information Act (FOIA) request
- Distributed data are accompanied by appropriate documentation
- Sensitive data are identified and protected from unauthorized access and inappropriate use

Depending on the type of data, data products may be available on an NGPN public website, via the NPS Data Store, or through NPS-wide databases such as NPSpecies and NatureBib. Data may be accessed from Regional, Network, or park data servers protected with read-only access or be available on FTP sites, CDs, DVDs, or hard drives. Some data will be available from external repositories such as EPA STORET and the High Plains Regional Climate Center.

Leafy wildparsley (*Musineon divaricatum*) at Badlands National Park

Ownership, FOIA, and Sensitive Data

The NGPN products are property of the NPS; however, the Freedom of Information Act (FOIA) establishes that any person may access federal agency records not protected from disclosure by exemption or by special law enforcement record exclusions. The NPS is directed to protect information about the nature and location of sensitive park resources under an Executive Order and four resource confidentiality laws (Appendix E). If disclosure could result in harm to natural resources, the records may be classified as "protected" or "sensitive" and public access to data can be restricted. The NPS recognizes the following resources as sensitive:

- Endangered, threatened, rare, or commercially valuable National Park System resources
- Mineral or paleontological sites
- Objects of cultural patrimony
- Significant caves

The Network will comply with all FOIA restrictions regarding the release of data and information, as instructed in NPS Director's Order #66 and accompanying Reference Manuals 66A and 66B. Classification of sensitive data will be the responsibility of Network staff, park superintendents (or their delegates), and project managers. Network staff will classify sensitive data on a case-by-case, project-by-project basis. The staff will work closely with project managers to ensure that potentially sensitive park resources are identified, information about these resources is tracked throughout the project, and potentially sensitive information is removed from documents and products that will be released outside the Network.

Data Archiving and Records Management

Archives of project data will include: project documentation; data in raw, verified, and analyzed conditions; metadata; supporting files (e.g., digital photographs and maps); and all associated reports. Final deliverables from project data will be added to existing libraries and databases.

In most instances, administrative documents, natural history specimens, photographs, audio tapes and other materials are essential companions to digital data. Direction for managing many of these materials (as well as digital materials) is provided in NPS Director's Order 19: Records Management (2001) and its appendix, NPS Records Disposition Schedule (NPS-19 Appendix B, revised 5-2003). Director's Order 19 states that all records of natural and cultural resources and their management are considered mission-critical records (necessary for fulfillment of the NPS mission) and must be permanently archived.

The NGPN data management approach ensures that project managers comply with archival directives. Whenever possible, physical products of a project (e.g., reports, maps, photographs, or notebooks) will be cataloged and archived by the park(s) involved with the project. When this is not possible, these physical items will be stored in other NGPN offices. Physical specimens, such as plants and animals, will be housed at appropriate institutions.

Water Quality Data

Water quality data are managed according to guidelines from the NPS Water Resources Division. The water quality component of the Natural Resource Challenge requires that Networks archive all water quality data collected as part of the monitoring program in a STORET (STORage and RETrieval; EPA 2008) database maintained by the NPS Water Resources Division (WRD, http://www.nature.nps.gov/water/infoanddata/index.cfm). In accordance with these guidelines, the desktop database application NPSTORET will be used to enter, store, document, and transfer water quality data. The NGPN oversees the use of NPSTORET per the Network's Water Quality monitoring protocol and ensures that data are transferred at least annually to the NPS Water Resource Division for upload to the STORET database.

Implementation

The NGPN Data Management Plan contains practices that may be new to Network staff and collaborators. With a few exceptions, however, the DMP does not include any new requirements. Almost every requirement stipulated in the Plan comes from law, Director's Orders, or the National I&M Program. The DMP helps put these requirements into context and provides necessary operational guidance. To successfully implement these requirements and produce permanently available, useful, high-quality information, all participants in the Network's monitoring program will play important roles in this data management system.

Chapter 7
Data Analysis and Reporting

Put it before them briefly so they will read it, clearly so they will appreciate it, picturesquely so they will remember it and, above all, accurately so they will be guided by its light. —Attributed to Joseph Pulitzer

A primary role of the I&M Program is to analyze, synthesize, and report inventory and monitoring data to park superintendents, other NPS managers and planners, scientists, interpreters, and the general public (Figure 7-1). Useful information comes from collecting and managing high-quality data that meets carefully determined objectives (Chapters 3-6). Effective analytical and communication approaches are needed to make these scientific data and information available for management decision-making and education (e.g., Carter et al. 2007). Data management, data analysis, and reporting of data and information will require a significant investment by the NGPN, with at least one-third of the core I&M Network funding devoted to these tasks.

Data and information relevant to park resources and Vital Signs monitoring come from numerous sources in addition to the NGPN I&M Program (Figure 7-1). The Network will promote integration and synthesis of data across protocols, programs, and disciplines. Program-wide synthesis and communication strategies will be developed further over the next few years. In addition, each monitoring protocol will specify analytical and reporting procedures relevant to that protocol. To be useful, information must be made usable and reported to these audiences

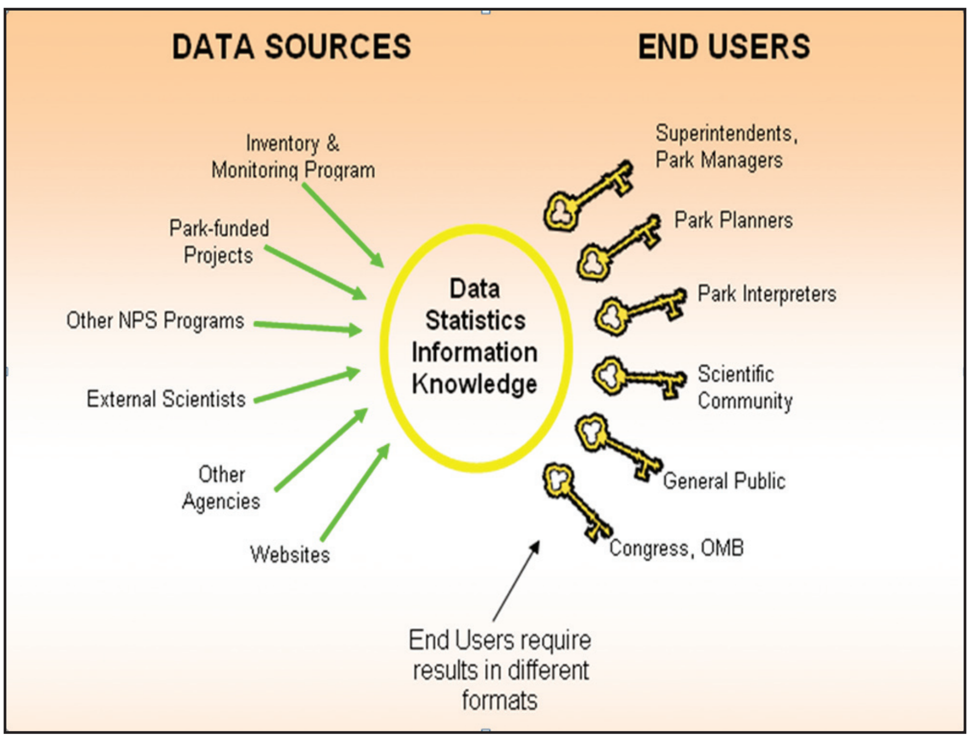


Figure 7-1. Flow of data and information through the I&M Program to diverse audiences.

in a timely manner; therefore, each monitoring protocol will establish firm schedules for data analysis and reporting, and reported information will be easily accessible via the Network's website. In this chapter, we provide a brief overview of how the NGPN will analyze its monitoring data and how the Network will report these data and results to park managers and other audiences.

Data Analysis

Data analysis uses statistical and graphical tools to extract patterns and information from raw data. We will use four general levels of analysis for our long-term monitoring data (Table 7-1):

1. Calculation of descriptive and summary statistics
2. Determination of current status for a monitored resource
3. Determination of trends in condition for a monitored resource
4. Synthesis of status and trend information across multiple resources to examine larger scale aspects of ecosystem condition and function

The frequency of analysis will vary among these four levels. Descriptive analysis may be performed at any time following data collection and entry and will be performed as part of annual or periodic reports. Analysis of status and trends will be performed on protocol-specific schedules. For example, for the [2-3] revisit design used for monitoring plant communities, a complete rotation through all monitored sites will take 5 years. Therefore, analyzing status and trends in vegetation community composition will occur every 5 years unless a park needs more frequent updates. Analytical inference about trend will carefully consider the multiple scales of temporal variation present in most NGPN resources. Regardless of long-term trends in an attribute, there likely will be shorter term, multi-annual fluctuations (e.g., several years of prolonged drought). Until continued monitoring has provided supplemental information about the normal range of variability, we will not be able to confirm whether a change is a long-term trend. Larger scale synthesis across multiple resources and monitoring efforts will occur as adequate amounts of data become available for all variables being analyzed.

For each protocol, analytical approaches will be tailored to the monitoring objectives, the sampling design used, and the intended audience. For example, the same data may be analyzed and presented in different ways to different audiences (e.g., intuitive graphical summaries to lay audiences vs. detailed explanation of statistical modeling for scientific audiences).

Rocky Mountain Bird Observatory staff observes birds at Wind Cave National Park

Table 7-1. Four general categories of data analysis for NGPN Vital Signs.

Analysis Category[a]	Description	Lead Analyst and Support
Data summarization/ characterization	Data screening and calculation of basic statistics of interest, including: • Measures of central tendency [mean, median], variation [range, variance] and correlations among variables in multivariate data sets • Identification of missing values and outliers [box-and-whisker plots, queries] • Graphical summaries and visual inspection of data Summarization procedures are specified in the monitoring protocols. Results will include measured and derived variables and matrices for community analyses.	Lead: I&M protocol lead or P.I. Support: Field crew leads, other park staff and I&M core staff
Status determination	Analysis and interpretation of resource status to answer the following: • Do observed values exceed a regulatory standard or a known ecological threshold? • How do observed values compare with the range of historical variability? • What is the precision and confidence in the status estimate? • How do observed values vary at park, Network, or regional scales? • Do these patterns suggest relationships with other factors not accounted for in the design? • What environmental factors function as covariates and influence the measurement values? Design-unbiased population estimators (e.g., Horvitz-Thompson) and/or model-based approaches (e.g., linear mixed-effects models for trend with estimate of a year-specific deviation [Best Linear Unbiased Prediction] to estimate status) will be used.	Lead: I&M protocol lead or P.I. Support: other park staff and I&M core staff, cooperators or Partners, regulatory and subject-matter experts

[a] The lead analyst will ensure that data are analyzed and interpreted within the guidelines of the protocol and program, but depending on required skills they may not actually perform the analyses.

Table 7-1. Four general categories of analysis for NGPN Vital Signs (continued).

Analysis Category	Description	Lead Analyst and Support
Trend evaluation	Evaluations of interannual trends will seek to address: • Is there continued directional change in indicator values over the period of measurement? • What is the estimated rate of change (and associated measure of uncertainty)? • How does this rate compare with rates observed from historical data, other indicators from the same area, or other comparable monitoring in the region? • Are there unforeseen correlations that suggest other factors should be incorporated as covariates? Analysis of trends will use graphical methods (Cumulative Sum [CUSUM] and control charts), and (generalized) linear mixed-effects models or other statistical models.	Lead: I&M protocol lead or P.I. Support: other park staff and I&M core staff; statisticians, cooperators or Partners, regulatory and subject-matter experts
Synthesis	Examination of patterns across Vital Signs will seek to gain broad insights on ecosystem processes and integrity. Analyses may include: • Tests of hypothesized relationships, congruence among indicators, and estimation of covariate effects • Development of analytical and predictive models • Integrative approaches [Direct ordination of community and environmental data, multiple regression, diversity indices, structural equation models, Bayesian hierarchical and graphical models] • Evaluation of competing *a priori*-specified models of dynamics in Vital Signs; multi-model inference Synthetic analysis will require close interaction with academic and agency researchers to examine ecological hypotheses that attempt to explain ecological relationships in NGPN ecosystems. Integration with results from other monitoring and research is critical.	Leads: Network Coordinator and Ecologist Support: Protocol leads, statisticians, data management staff, park staff, cooperators or Partners, regulatory and subject-matter experts

Reporting

We will utilize a diversity of approaches and outlets to disseminate monitoring results and to make the data and information more available and useful to our key audiences. Below we summarize several major categories of communication products, including those produced each year (Annual Administrative Report and Work Plan; project-specific Annual Reports), those produced periodically (briefings for park managers; Analysis and Synthesis Reports; scientific publications and presentations; program and protocol reviews), and those that are updated and maintained continuously or as needed (NGPN internet and intranet sites).

Annual Administrative Report and Work Plan (AARWP)

Each year the NGPN I&M Program will produce an AARWP to account for funding and program expenditures; to describe accomplishments and products for the last year; and to outline objectives and tasks for the upcoming year. The report serves as an administrative record of the program and as a tool to inform Network superintendents, other park staff, and regional and national NPS staff about the progress and accountability of our program. This information also is used by the National I&M Coordinator to produce an annual report to Congress. The Network I&M Coordinator is the lead on the report, with assistance from other I&M core staff. The annual report, before submittal to the National I&M Program Leader, must be approved by the Board of Directors and Regional I&M Coordinator.

Annual Reports for Specific Protocols and Projects

The primary purposes of annual reports for specific protocols and projects are to:

- Summarize and archive annual data and document monitoring activities for the year
- Describe the current condition of the resource
- Document changes in monitoring protocols
- Provide summaries and updates to NPS regional and national offices and to collaborators
- Increase communication within the Network

Most NGPN protocols will collect and summarize some data annually from at least a subset of parks. We plan to produce reports for each protocol every year, but the scope of the annual report may vary among years for each protocol. For example, for the Plant Communities protocol we will not conduct detailed analysis of current resource condition every year; rather, such analyses usually will occur only after a complete rotation through all sample sites (5 years at most parks for vegetation monitoring). If annual reports are not feasible (due to staff workload) or necessary (due to frequency of data collection) for some protocols, reports will be produced less frequently.

The primary audiences for these reports are park superintendents and resource managers, other Network staff, park-based scientists, and collaborating scientists. Wherever possible, annual reports will be based on automated data summarization routines built into the MS Access database for each protocol. The NPS I&M protocol lead (Chapter 8) will be responsible for producing the report. This may require working closely with other collaborators on the protocol to ensure timely reporting. Most annual reports will receive peer review at the Network level, although a few may require review by subject-matter experts from universities or other agencies.

Periodic Briefings for Park Managers

To increase the availability and usefulness of monitoring results, the Network Coordinator will organize periodic briefings for park managers that include visits to each park to present results from monitoring to all park staff. Protocol leads and principal investigators will participate when feasible. During this briefing, I&M staff will summarize key findings or “highlights” from the past year’s work and identify potential management action items. Briefings may include specialists from other NPS programs such as the NPS Air Resources Division (ARD), NPS Water Resources Division (WRD), and Northern Great Plains Fire Ecology Program (FireEP), as well as external collaborators, to provide managers with an overview of the status and trends in their park's natural resources. In preparation for these briefings, as well as for use on I&M web sites, protocol leads and scientists will prepare one- to two-page resource briefs that summarize the key findings and recommendations for their protocol or project. In recognition of the limited time available to managers for deciphering complex technical documents, these briefs will communicate clear, short messages with plain text and pictures (Lewis 2007). In addition to these park-specific briefings, I&M core staff present updates on monitoring issues and results during annual meetings of the superintendents (including the Board of Directors) and of the Technical Committee.

Analysis and Synthesis Reports

The purposes of analysis and synthesis reports are to:

- Determine trends and ranges of variability in Vital Sign measures
- Determine if there are changes in resource condition outside the normal range of variability
- Assess whether current monitoring is sensitive enough to detect changes of concern to managers and ecologists
- Estimate and interpret relationships among resources and between drivers/stressors and responses measured at comparable or multiple scales
- Provide multi-park, regional, or national contexts for these results
- Help managers assess current management practices and recommend alternative management strategies to be assessed in an adaptive-management framework
- Provide summary reports and updates to collaborators

These reports are written at 5–10-year intervals for resources sampled annually, unless there is a pressing need for information to address a particular issue. For resources sampled less frequently, or that have a low rate of change, intervals between reports may be longer. These reports will integrate information from multiple protocols to provide a broader examination of ecosystem conditions (e.g., by integrating results from water quality and hydrologic monitoring). A NGPN ecologist, data manager, or the Network Coordinator will initiate these reports, often by working closely with external collaborators involved in the relevant monitoring. The primary audiences for these reports are park superintendents and other resource managers, park-based scientists, Network staff, and collaborating scientists. These reports will receive external peer review by at least three subject-matter experts.

Protocol and Program Reviews

Periodic protocol and overall program reviews are essential components of quality assurance for any long-term monitoring program. A review of each NGPN protocol will be conducted before the first 5-year Analysis and Synthesis Report. Thereafter, protocols will be reviewed at approximately 10-year intervals or more frequently as needed.

As the first step in each review, a Network or park scientist, outside contractor, or academic is enlisted to analyze data and evaluate results produced by the monitoring protocol. Subject-matter experts review the protocol and reports it has produced. Next, subject-matter experts and peers attend a workshop to discuss the protocol, to examine the results of the data analysis and evaluation, and to determine if the protocol is meeting its specific objectives and is able to detect a meaningful level of change. The group recommends improvements to the protocol. Finally, the protocol P.I., Network Coordinator, or contractor writes a report summarizing the workshop. The report is reviewed and edited by the participants; the final report is then posted on the NGPN website, and copies are sent to NPS Regional and National I&M Program offices.

As described in Chapter 8, the Network I&M Program will have a "Start-up Review" approximately 3 years after this monitoring plan has been approved and implemented. Subsequent program reviews will occur at approximately 5-year intervals. These reviews will assess program structure, function, and monitoring results to determine whether the program is achieving its objectives, and whether these objectives are still relevant, realistic, and sufficient.

Scientific Journal Articles, Book Chapters, and Presentations

Putting a program's methods, analyses, and conclusions under the scrutiny of a scientific journal's peer-review process is basic to science. Defensibility of contentious management decisions is increased if the supporting results have been peer reviewed by external scientists. By producing scientific publications and presenting information at professional meetings, the Network can contribute to scientific understanding of this region's ecosystems and engage external scientists in supporting and building on our monitoring efforts.

Lead authors on scientific publications and presentations may include protocol leads, NGPN ecologists, other NPS staff, or external collaborators. Journals or book editors will handle final peer review of manuscripts. However, such peer review is imperfect at screening out studies with faulty designs, inadequate data, questionable analyses, or reckless interpretation (Ford 2000:419; Hilborn 2006). Therefore, the Network will ensure that manuscripts submitted by core I&M staff meet basic standards for scientific and statistical validity before submission to external outlets. In some cases, partners from other agencies (e.g., USGS) with stringent presubmission internal review requirements will be coauthors on NPGN submissions, and no additional presubmission reviews will be needed.

Internet and Intranet Websites

Websites are a key tool for promoting communication, coordination, and collaboration among the many people, programs, and agencies involved in the Network monitoring program. The 32 I&M Networks are required to develop and maintain a parallel series of intranet (NPS only) and internet (public) websites to communicate and disseminate inventory and monitoring results to park managers, planners, interpreters, and other internal and external audiences. Network staff will use these websites as a primary means of making Resource Briefs, data summaries, progress reports, technical reports, trend reports, interpretive materials, and other information available to internal and external audiences (Table 7-2). The assistant data manager will be the lead on web-based reporting.

Report Scheduling and Outputs

To ensure reporting efforts remain a priority for all protocol leads, the budgets and staff time allotted for each protocol will include adequate funding to support the production of required annual and periodic reports. Each protocol will establish annual deadlines and procedures for basic analyses and reports. As these deadlines are determined, the NGPN will develop schedules for updating internet-based communication.

Protocols, annual protocol/project reports, trend analysis and synthesis reports, and other products of the I&M efforts will be published in the NPS Natural Resource Report or Natural Resource Technical Report series unless they are published in a similar numbered report series of a collaborating agency or university, or in a peer-reviewed journal. Reports published in these numbered series meet a set of minimum standards for scientific credibility (generally through peer review), are designed and published in a professional manner, and are likely to be accessible much longer than traditional internal government reports. All journal articles, book chapters, and other written reports will be listed in the Network's Annual Administrative Report and Work Plan provided to Network staff, Technical Committee, Board of Directors, and regional and national offices each year. Additionally, all scientific journal articles, book chapters, and written reports will be entered into the NatureBib bibliographic database.

Collaborative Reporting and Synthesis

The success of the NGPN I&M Program will depend on its ability to leverage its limited core funding by collaborating with other monitoring efforts and integrating data from other programs. Many of the core NGPN protocols will rely heavily on data collected by parks, states, and other agencies such as the USGS and the USFS. When possible, the Network will collaborate closely with these other entities to facilitate effective reporting and synthesis of these data.

Although I&M core staff will take the lead on most reports described above, this staff will collaborate closely with park resource specialists to interpret monitoring results and assess management implications of these results. As the program becomes operational, an outreach strategy may be developed that utilizes the expertise of park interpretative specialists to communicate what we are learning about park ecosystems to park visitors and other audiences.

With clear and timely messages communicated effectively, the I&M Program can contribute information directly into the decision-making process. However, monitoring information is only one of many sources of information used by NPS staff for management decisions (Figure 7-2). The NGPN, and NPS as a whole, increasingly strives to integrate information from these diverse sources. Like all I&M Networks, the NPGN will participate in an NPS-wide "Connect the Dots" effort, a strategic, long-term framework for coordinating the efforts of the I&M Networks, Resource Condition Assessment Program, park planning, park-funded monitoring and research, and other efforts (available on the NPS intranet at http://www1.nrintra.nps.gov/im/monitor/ConnectTheDots.cfm). Data and information gained through Vital Signs monitoring will be integrated by each park with other sources of information to summarize the desired and current conditions of park resources. The I&M Program will contribute to this effort and, in turn, these summaries will help I&M staff integrate data and information from other sources into analyses of Vital Signs monitoring data.

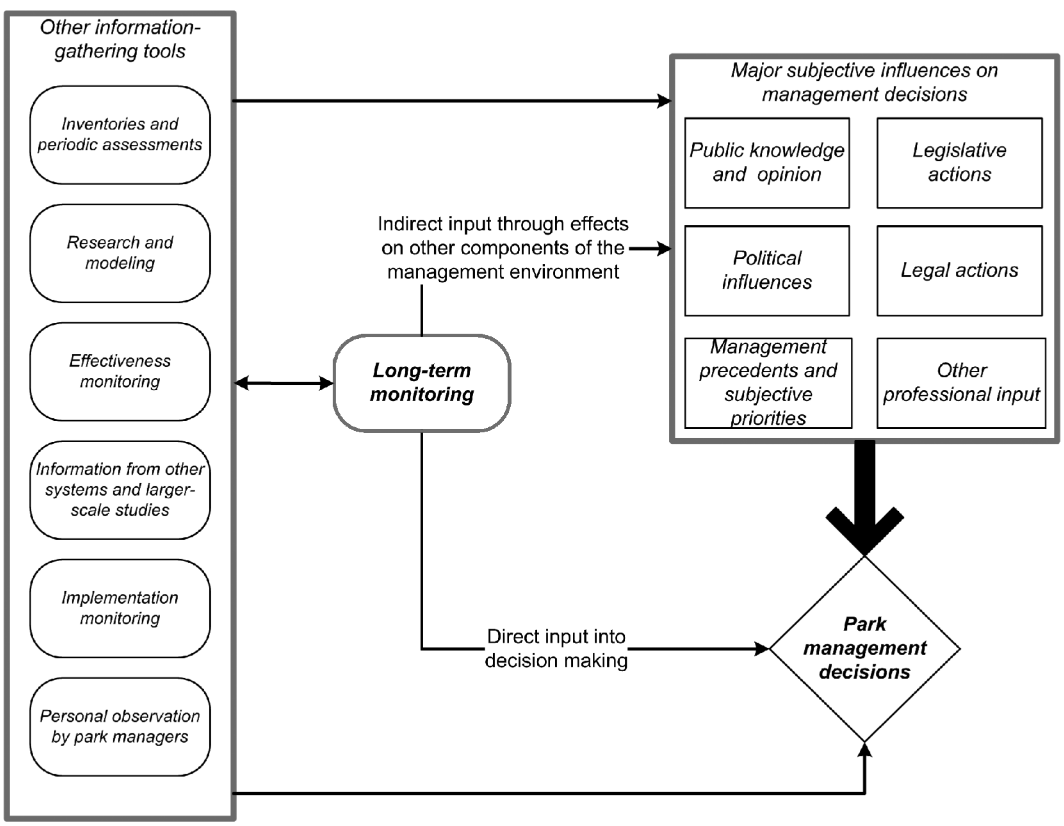


Figure 7-2. Factors affecting park management decisions.

Table 7-2. Current and planned internet-based communication by the NGPN. NGPN website: http://science.nature.nps.gov/im/units/ngpn/

General Focus	Audience	Description and Purpose	Availability
Vital Sign summaries	Parks, public, external scientists	Provide overviews and in-depth descriptions of Vital Signs, protocols, annual monitoring reports, and status/trends of resources.	2009
Resource Briefs	Park superintendents and interpreters; public	Provide one-page summaries for selected resources, including importance of the resource, its current status, and how it is being managed or monitored.	2010
Other reports	Parks, public, other NPS and external scientists	Make reports, scientific papers, and presentations easily accessible. Repository of all reports after peer review to ensure accessibility in standard formats.	2005
Static data	Park superintendents and resource specialists, external scientists	Archive and make QA/QC-ed data accessible for external analyses and syntheses. Allow dynamic queries of monitoring databases. Provide easily accessible species lists for each park. Provide a portal for obtaining weather and climate data collected by other entities.	2006 (species lists) 2010 (other components)
Real-time data and alerts	Park superintendents and resource specialists; other NPS scientists and partners	Display real-time data transmitted from remote units (e.g., ozone and water quality stations); automatically generate email alert to parks and other staff if measurements exceed a specified threshold.	2011
Spatially explicit data	Park superintendents and resource specialists (intranet)	Map monitoring locations and other park features (currently using Google Earth); link locations to tabular and photo databases so that location can be visualized and information and data for each location can be queried dynamically.	2006 (mapping) 2010 (data queries)
Other outreach	Parks, public	Provide brochures, photos, videos, and other material highlighting the I&M Program, monitoring results, and ecology of parks.	2007
Administrative records	Parks and other NPS personnel	Archive NGPN Charter and minutes for meetings of Board of Directors and Technical Committee.	2004

Chapter 8
Administration / Implementation of Monitoring Program

The governing structure of the NGPN I&M Program includes a Board of Directors and a Technical Committee comprised of NPS staff. Program administration is governed by the Service-wide I&M Program, which provides monitoring program goals and overall planning guidance. Network core I&M staff and funding are overseen by the NPS Midwest Region. The I&M core staff are managed by a Network Coordinator; the core staff will collaborate closely with Network park staff, other NPS staff, and outside partners to implement the monitoring efforts described in earlier chapters.

This chapter provides more details on the administrative and governing structure of the NGPN I&M Program and describes the roles of NPS staff in Network operations. Much of this chapter is a summary of guidance and requirements from the National I&M Program, as well as from the Northern Great Plains Network Charter (Appendix F). We describe how this program is integrated with park operations, summarize key partnerships formed to date with other NPS and non-NPS programs, and outline review procedures for the program.

Roles of the Board of Directors and Technical Committee

The Board of Directors is responsible for ensuring the overall effectiveness of the NGPN's monitoring efforts and for ensuring that funds are spent for the intended purpose. The Board makes decisions regarding the development and implementation of the NGPN's monitoring strategy, including approval of annual budgets, work plans, and staffing plans. (Amendments to the NGPN Charter require signatory approval of all Network superintendents.) The Board promotes overall accountability of the program.

Five park superintendents are the voting members of the Board (Table 8-1) with membership rotating through the 13 NGPN parks. Each superintendent serves a 2-year term; each year a superintendent in the second year of their term is selected as chair. The rotation cycle is designed so that the Board always includes members from large and small parks, and from parks in the northern, central, and southern parts of the Network. The Regional and Network Monitoring Coordinators are advisory Board members.

Table 8-1. Rotation of Board of Directors of the NGPN.
Rotation schedule among parks for each seat on the board. Two seats starting in Fiscal Year 2007 are serving 3-year terms; thereafter all terms are for 2 years. Three seats rotate among parks in odd years; two seats rotate in even years.

Seat 1	Seat 2	Seat 3	Seat 4	Seat 5
2007-KNRI	2007-JECA	2007-MNRR	2007-DETO (3 yr)	2007-MORU (3 yr)
2009-SCBL	2009-THRO	2009-FOLA		
			2010-BADL	2010-AGFO
2011-FOUS	2011-WICA	2011-NIOB		
			2012-KNRI	2012-JECA
2013-MNRR	2013-DETO	2013-MORU		
			2014-SCBL	2014-THRO
2015-FOLA	2015-BADL	2015-AGFO		
			2016-FOUS	2016-WICA
2017-NIOB	2017-KNRI	2017-JECA		
			2018-MNRR	2018-DETO

The Technical Committee (TC) is the scientific and operational advisory body of the NGPN. The following roles of the TC are specified in the NGPN Charter:

- Compiling and summarizing existing information about park resources
- Recommending which resources should be monitored at the parks
- Recommending which monitoring efforts by other agencies and nongovernmental organizations should be tracked by the Network
- Recommending protocols, procedures, and frequencies for collecting data
- Recommending personnel and funding priorities for the I&M Program
- Participating in the preparation and review of Annual Work Plan and Annual Report
- Participating in the preparation of 5-Year Program Reviews

The TC is comprised of one representative from each park (designated by the park superintendent) and the Regional and Network Coordinators. The managers of the Northern Great Plains Fire Ecology Program (FireEP) and the Northern Great Plains Exotic Plant Management Team (EPMT) are informal participants in most Committee activities. The TC meets at least annually.

The I&M Program core staff typically communicate with park staff through the park TC representative (e.g., communicating needs for assistance from interpretation, maintenance, and other park programs). Likewise, the TC representative ensures that park staff gets relevant information from I&M Program core staff.

Roles of the Network Coordinator and Staff

The Network Coordinator facilitates communication among the many people involved in the monitoring program, including the TC, Board of Directors, national I&M Program, NGPN parks, and cooperators. The Coordinator works with the TC to establish objectives for the program, to determine implementation strategies, and to help meet the long-term data needs of the NGPN parks. The Coordinator is responsible for managing the program's budget and ensuring fiscal accountability, with oversight from the Board. The Coordinator is the liaison between the Board and TC, and documents their meetings (available on the NPS intranet site at http://www1.nrintra.nps.gov/im/units/ngpn/reportpubs/meetingminutes.cfm). The Coordinator directly supervises most I&M Program permanent staff. In coordination with the Board and TC, the Coordinator is responsible for hiring, conducting performance reviews, and handling other supervisory and administrative functions. Finally, the Coordinator ensures regular and thorough reviews of the program.

The Network Coordinator and all I&M Program core staff are duty stationed in Rapid City, South Dakota. These core staff members include seven permanent staff, two term positions, and approximately nine temporary staff (Figure 8-1; Table 8-2).

Roles of the Washington Office / National I&M Program and Regional Office

The National I&M Program of the Washington Office provides overall strategic guidance for all NPS I&M Networks. It oversees and ensures that the NGPN meets reporting and workplan requirements. For example, the National I&M Program Leader approves the Network's Annual Administrative Report and Work Plan (AARWP). This office consolidates information from all I&M annual reports and databases into an annual report to Congress. The Washington Office provides technical assistance and support relating to data management, specialized training, national-level meetings, and programmatic reviews. The Network utilizes resources made available by the National Program meeting some data needs common to all I&M Networks. For example, National I&M

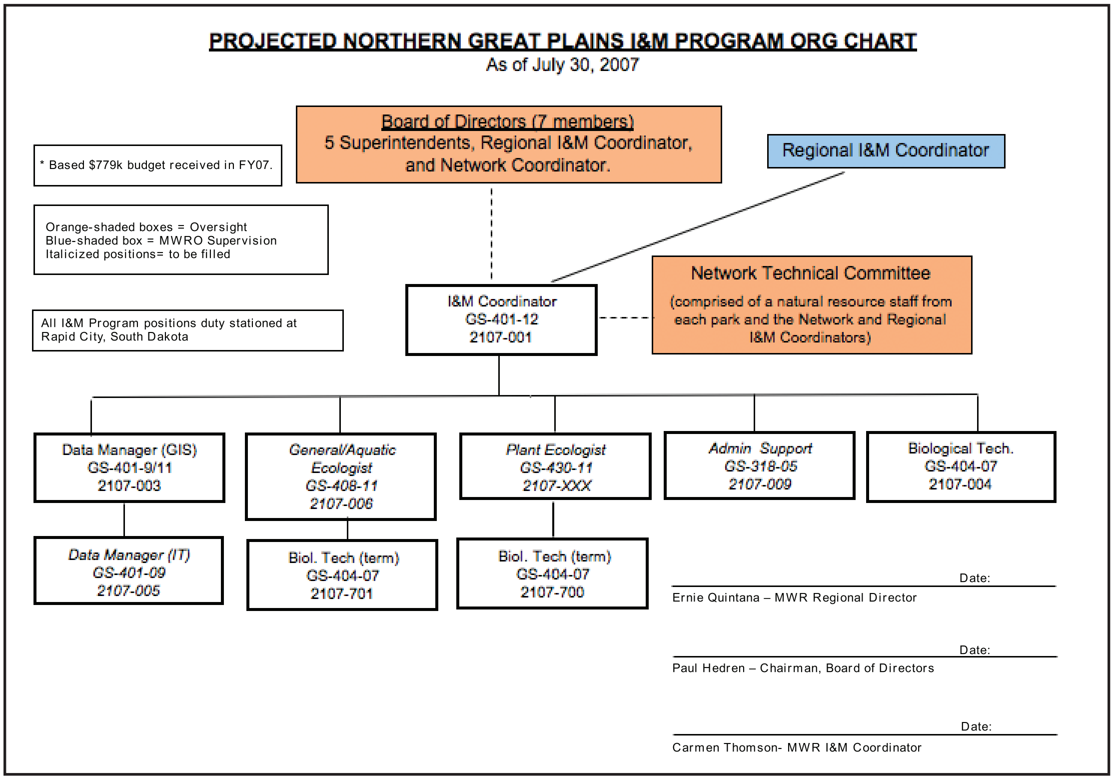


Figure 8-1. Organization chart for the NGPN. Signed by the Midwest Regional Director, 2007.

Program staff have developed an internet portal (NPClime) for access to weather/climate data; the NGPN Weather and Climate protocol ties into this national effort.

The Midwest Regional Office, particularly the Regional I&M Coordinator, also actively guides and oversees the NGPN. As described above, the Regional Coordinator sits on the Network Board of Directors and TC, supervises the Network Coordinator, serves as the key official for Natural Resource Reports and Technical Reports by the Network, and facilitates operational reviews. The Regional Coordinator coordinates Vital Signs monitoring with other Networks and ensures effective communications between parks, NGPN I&M core staff, regional staff, and National I&M Program staff.

Integration with Park Operations and Roles of Other NPS Staff

Other NPS personnel play critical roles in collecting and interpreting monitoring data from NGPN parks (Table 8-3). The Network I&M Program, FireEP, EPMT, and other NPS entities collaborate closely to maximize their efficiency and effectiveness (Table 8-4). In addition, the NGPN interacts with and shares expertise with other I&M Networks. For example, the NGPN has received much informal input about sampling design issues from staff of other Networks. Integrated multi-Network inference is also a goal when it is feasible without compromising the NGPN's primary focus on park-level inference. The NGPN borders the Great Lakes, Rocky Mountain, Southern Plains, and Heartlands I&M Networks (http://science.nature.nps.gov/im/networks.cfm). The latter two Networks, together with the NGPN, encompass most of the U.S. portion of the Great Plains and are examining potential for standardizing a portion of the grassland vegetation protocols to facilitate biome-wide analyses of species richness.

Table 8-2. Primary responsibilities of NGPN I&M staff.

Position	Level[a]	Type	Role
Network Coordinator	12	PFT	Coordinates all aspects of the monitoring program. See text.
Data Manager (GIS)	11	PFT	Responsible for coordination of a comprehensive data management program including both tabular data and spatial data and information. Lead contact on Landscape Pattern and Dynamics protocol. Assesses remote-sensing needs for the program. Works with Assistant Data Manager to assure that spatial data are properly collected, archived, and disseminated. Provides technical assistance to parks as requested.
Assistant Data Manager (Tabular/IT)	9	PFT	Oversees tabular databases and spends most time on data management. Designs software architecture for internet dissemination of program information. Works with investigators to design appropriate databases that facilitate data integration. Lead contact on Weather and Climate and Air Quality protocols.
General/Aquatic Ecologist	11	PFT	Serves as principle investigator, or develops partnerships with external investigators, for Water Quality, Surface and Groundwater Hydrology, Stream and River Channel Characteristics, and Cave Water and Meteorology protocols. Designs studies, hires and supervises seasonal personnel, leads field studies, conducts analyses, and reports results. Provides technical assistance to parks as requested.
Plant Ecologist	11	PFT	Principle investigator for Plant Communities and Exotic Plant Early Detection protocols. Designs studies, hires and supervises seasonal personnel, leads field studies, conducts analyses, and reports results. Provides technical assistance to parks.
Biological Technician (Data/Wildlife)	7	PFT	Responsible for routine data entry projects. Lead Network contact on national databases such as NPSpecies. Lead contact on Soundscape and Land Birds protocols. Conducts field studies and assists other investigators as needed. Provides technical assistance to parks as requested.
Administrative Support	5	PFT	Performs office administrative tasks in support of program goals (budget management, personnel management, document management, preparation of memos, and other office needs). May assist with other special projects.
Biological Technician (General)	7	TFT	Assist the General Ecologist in field studies and office work, including data management and reporting. Lead contact on Prairie Dogs protocol. Provides input to parks about other park-specific monitoring and inventory projects.
Biological Technician (Plants)	7	TFT	Assists the Plant Ecologist in field studies and office work. Provides input to parks about other projects.
Biological Technician (Aquatic)	5	Temp	Assist the General Ecologist in field studies and data processing during summer (~three positions).
Biological Technician (Plants)	5	Temp	Assist the Plant Ecologist in field studies and data processing during summer (~six positions).

[a]Level = GS level. Type: PFT = permanent full time; TFT = term full time; Temp = temporary.

Table 8-3. Roles of other park and NPS staff in NGPN monitoring.

NPS Entities	Role
Jewel Cave NM and Wind Cave NP cave specialists	These specialists are the leads on data collection for the Cave Water and Meteorology protocol and will collaborate closely with I&M core staff on analysis and reporting.
Other NPGN park resource staff and other park staff	Park staffs, through their Technical Committee representatives, ensure that the I&M Program meets their needs. Park staff conducts monitoring, data management, and reporting for selected Vital Signs not implemented with I&M funding. Park staff assists with Vital Signs monitoring for protocols where regular efforts that take little time are needed, or when expertise on park resources is needed. Park staff leads outreach efforts. As protocols are developed, the Network will identify additional sampling efforts where park staff can most efficiently lead or assist with monitoring. For example, prairie-dog monitoring may combine remote sensing to map active colonies with on-the-ground checks and ground truthing by park staff. As part of the Landscape Pattern and Dynamics protocol, the NGPN will develop a strategy for maintaining an accurate spatial database of vegetation treatments implemented by parks. Similarly, park staff can help the appropriate I&M core staff be aware of and document unusual disturbance events. As part of the Exotic Plant Early Detection protocol, knowledgeable park staff will help detect presence of any high-threat species.
FireEP Personnel	The FireEP contributes to the I&M Program's vegetation monitoring so that the Plant Communities protocol meets the goals and objectives of both programs. The FireEP contributes a crew of four people for intensive plot sampling for one pay period, and four people for extensive plot sampling for ~two pay periods, each field season. Plant Communities data are entered, stored, and managed by the I&M Program, but shared between the two programs for analysis purposes. The FireEP regularly map their fuels treatments; these data will be accessed for the Landscape Pattern and Dynamics protocol.
EPMT	The EPMT Liaison works closely with the I&M Program regarding exotic plant early detection efforts. The EPMT Liaison will also provide spatial data of exotic plant treatment activities to the I&M Program for the Landscape Pattern and Dynamics protocol. The two programs will work closely in developing domain analyses of vegetation monitoring sites in relation to changes after treatments.
Heartlands I&M Network	As monitoring from the Prairie Cluster Prototype program for AGFO and SCBL is transferred to the NGPN, the two Networks will work together on consistency of protocol applications, protocol changes, calibration of old and new protocols, and analysis of data conducted before and after the transition.
NPS Air Resources Division (ARD)	The ARD coordinates air quality monitoring (ozone, particulates, deposition, visibility) for NPS. For the Air Quality protocol, the NGPN relies on ARD data collection and summaries of trends relevant to NGPN parks. If the Network funds additional monitoring to fill in high-priority gaps, ARD will take the lead on establishing monitoring stations, handle protocols for data collection, and collaborate on reporting.
NPS Water Resources Division (WRD)	The NGPN receives annual funding from WRD for monitoring water quality. The WRD provides guidance on quality assurance, monitoring protocols, Standard Operating Procedures, lab measurements, data management and archiving in STORET, data analysis, and equipment/software purchases. In addition, the WRD tracks the designated uses and impairments for water bodies of Network parks.
NPS Night Sky Team	If funding permits, the Night Sky team will collaborate with the NGPN on protocol development, data collection, data management, and reporting.
NPS Natural Sounds Program (NSP)	The NSP will provide data storage, technical assistance, use of equipment, and assistance with data analysis for the Soundscape protocol.

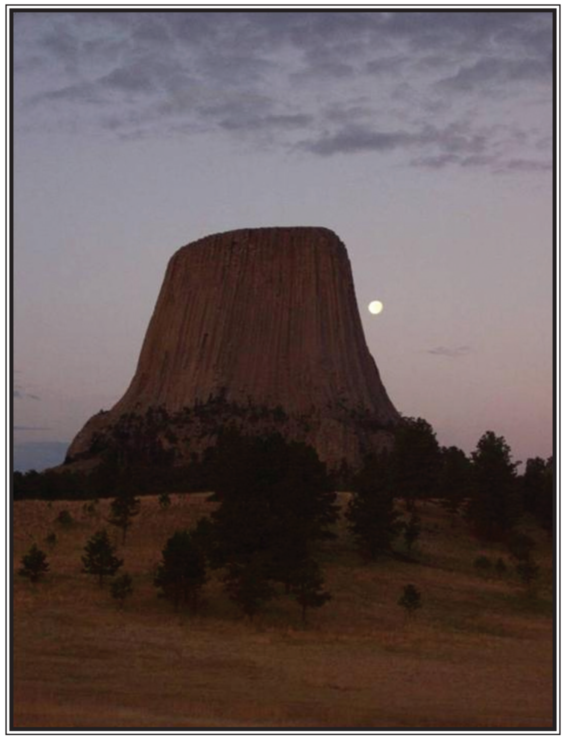
Table 8-4. Integration of the I&M Program with other NGPN NPS programs.

NPS Program	Integration with I&M Program
NGPN park natural resource staff	The I&M core staff collaborates with park resource managers by helping to develop funding proposals, providing input for studies of park-specific resource concerns, and assisting with analyses of existing data. As the I&M Program is implemented, parks may utilize I&M expertise to help manage other natural resource data, such as other monitoring data, collected by individual parks.
NGPN park natural resource staff, FireEP, EPMT, and I&M Partners	The I&M staff will collaborate with FireEP, EPMT, and park staff to produce a toolbox of protocols that parks can implement for effectiveness monitoring of specific management actions.
NGPN general park staff and interpretive specialists	I&M core-staff ecologists and park staff, especially interpretive specialists, can educate each other about the natural resources of each park. In turn, interpretive staff can help communicate information gained from the monitoring program to parks and the general public. Park staff can make I&M core personnel aware of unusual events, situations that could hinder upcoming sampling, and changes affecting resources being monitored (e.g., new developments around a park).
NGPN park law enforcement and maintenance staff	Communication between I&M field staff and park law enforcement will be essential to help ensure staff safety and park security. Park staff can educate I&M core staff about specific hazards and collaborate on plans for dealing with emergencies. The I&M core staff may observe items that need examination by law enforcement or maintenance staff.

Partnerships

Given the small size of the NGPN's I&M core staff versus the broad disciplines covered by its Vital Signs, we rely heavily on partnerships with experts from other entities. The Network has developed numerous partnerships to assist with development and implementation of this plan (Table 8-5) and relies on data collected by other programs.

For example, the Weather and Climate protocol will depend on data from climate/weather networks operated through NOAA (NWS COOP and CRN stations) and the Interagency Fire Center (RAWS stations; Table 1-8, Chapter 1). Such data may be accessed in the absence of formal agreements, or through agreements made at the National I&M, regional, or Network level.



Full moon at Devils Tower National Monument

Table 8-5. Current partnerships by the NGPN.

Agency/Program	Format	Project
National Park Service ARD	Contract	The ARD is working with the NGPN to assess current gaps in monitoring for ozone, nitrogen fertilization, and mercury.
National Park Service NSP	Under development	The NGPN and NSP are discussing collaboration to use NSP expertise and equipment and provide a testing ground for biological soundscape monitoring protocols.
USGS Northern Prairie Wildlife Research Center	Informal	Dr. Amy Symstad from the USGS-BRD, Jamestown, ND, office is the lead on the Plant Communities protocol development. She has implemented field trials for this protocol development, and provides other major services and products to the Network (e.g., an assessment of old-growth at MORU).
USGS South Dakota Water Science Center	Interagency Agreement	The USGS will summarize critical attributes and processes in NGPN aquatic ecosystems, and cooperate with the Network to identify potential monitoring objectives for these systems.
U.S. Forest Service	Interagency Agreement	The NGPN developed interagency agreements with the U.S. Forest Service for mammal inventories and plant studies. The NPS currently houses a research-grade USFS ecologist who has provided input about Network ecosystems and monitoring.
University of Missouri	Cooperative Ecosystem Studies Unit agreement (CESU)	The NGPN formed a 5-yr agreement (expires 2010) with Dr. Joshua Millspaugh to develop the Network's monitoring plan and provide scientific and quantitative input. An MU post-doctoral researcher is the lead on the monitoring plan.
University of Maryland Center for Environmental Science (UMCES)	CESU	The UMCES is working with the NGPN to develop conceptual diagrams for selected Network parks and will work with the I&M Program to develop a science communication plan.
Cornell University Laboratory of Ornithology	Cooperative Agreement	The objective of this collaboration is to conduct a pilot research project on the biological soundscape to help develop the Network's Soundscape protocol.
South Dakota School of Mines and Technology	CESU and Informal	Dr. James Stone is working with the EPA and the State of South Dakota on a comprehensive study of mercury. Money from the NPGN allowed the study to be extended to ND, WY, and NE. The Department of Electrical and Computer Engineering and the I&M staff are collaborating on Senior Design Projects to enhance the Network's remote-monitoring technology.
Rocky Mountain Bird Observatory (RMBO)	Cooperative Agreement, CESU	This agreement was developed when RMBO conducted bird inventories for the NGPN. The nonprofit organization is helping assess options for bird monitoring in Network parks and likely will handle sampling for the Land Birds protocol.

Review Processes for the NGPN I&M Program

The accountability and effectiveness of this program are reviewed at regular intervals. A yearly opportunity for review comes during preparation of the AARWP (Chapter 7). The annual plan, before submittal to the National I&M Program Leader, must be approved by the Board of Directors and Regional I&M Coordinator, allowing them to review the Program's progress and direction. Similar opportunities are provided by the annual meetings of the Board of Directors, TC, and entire Network. These meetings also identify strategies for responding to unexpected ecological or budgetary changes affecting monitoring efforts.

Major formal evaluations occur during program and protocol reviews. Like all I&M Networks, the NGPN will conduct a full review of its I&M Program 3 years after approval of the Network's monitoring plan. This "Start-up" review focuses primarily on operational and administrative aspects of the monitoring program and examines whether the NGPN I&M Program is set up to succeed. The review will allow Network staff to evaluate progress in relation to objectives and development schedules specified in the monitoring plan, to develop a road map for completing and implementing its first set of protocols, and to identify needed adjustments. The review panel is led by the National I&M Program Leader and includes the Regional I&M Coordinator and others who have experience with long-term monitoring programs.

Thereafter, program reviews will occur at approximately 5-year intervals. These reviews will evaluate administrative and technical aspects of the program, including program effectiveness, accountability, structure and function, scientific rigor of protocols and associated data, integration with park activities, and effectiveness of outreach and partnership activities. Program reviews provide the principal basis for any significant changes in program direction and may lead to amendments to the Charter and Monitoring Plan.

As the building blocks of the NGPN's monitoring program, individual protocols also will undergo review. The strength of monitoring comes from repeated application of a consistent protocol over many years. This continuity is lost when there are major mid-stream changes in methodology; therefore, protocol reviews will be performed most frequently in the early stages of monitoring. During each protocol review, the Network will review the scientific, technical, and administrative aspects of the protocol and its implementation. The protocol lead and cooperators will provide materials for review by external subject matter experts, park professional and management staff, and the TC. This review will evaluate whether protocol objectives are being met, whether the Network needs to modify its methods or assess new techniques, and whether information is appropriately managed and reported.

Fuzzytongue penstemon (*Penstemon eriantherus*) at Agate Fossil Beds National Monument

Chapter 9
Schedule

Based on current funding, the NGPN plans to develop and implement 12 protocols by 2014 (Table 9-1). Among the two top priority protocols, one (Plant Communities) will be completed in 2009, with initial monitoring planned for 2010. The other top priority protocol, Water Quality, will be completed in 2011.

Table 9-1. Schedule for development and implementation of 12 NGPN protocols.

Protocol[a]	Draft	Final Approval	Implementation	Protocol Development Lead[b]	Operational Lead[b]
Plant Communities	Jan 2007	Dec 2009	May 2010	Dr. Amy Symstad, USGS-BRD	Plant Ecologist
Water Quality	Oct 2010	Apr 2011	May 2011	Bio. Tech. and USGS SD Water Science Center	Ecologist
Exotic Plant Early Detection	Mar 2011	Mar 2012	May 2013	Bio. Tech.	Plant Ecologist
Landscape Pattern and Dynamics	Jun 2011	Dec 2011	Mar 2012	Data Manager and collaborator TBD	Data Manager
Weather and Climate[c]	Jun 2011	Mar 2012	Jun 2012	Assist. Data Manager & National I&M Program	NPS National I&M staff and Assist. Data Manager for summaries/analysis
Surface and Groundwater Hydrology[c]	Oct 2010	Apr 2011	May 2011	Bio. Tech. and USGS SD Water Science Center	USGS and Ecologist for data collection; Ecologist for analysis/reporting
Land Birds	Apr 2011	Nov 2011	May 2012	Bio. Tech., w/ Rocky Mountain Bird Observatory (RMBO)	Bio. Tech., prob. with RMBO
Air Quality[c]	Nov 2011	May 2012	Jun 2012	Assist. Data Manager and Air Resources Division (ARD)	ARD for data collection; ARD and Assist. Data Manager for reporting
Stream and River Channel Characteristics	Dec 2012	Jul 2013	Mar 2014	Data Manager	Ecologist or Data Manager
Soundscape	June 2010	Dec 2010	Mar 2011	Bio. Tech. and Natural Sounds Programs (NSP)	Bio. Tech. and NSP
Cave Water and Meteorology	Dec 2010	Jun 2011	Dec 2011	JECA and WICA cave staff, and Bio. Tech.	JECA, WICA, and Ecologist
Prairie Dogs	Mar 2012	Dec 2012	Jun 2013	Bio. Tech. and park staff	Bio. Tech. and park staff

[a]Protocols are listed in approximate order of priority for development, with the exception of protocols applicable to only one or a few parks (Prairie Dogs; Cave Water and Meteorology). The length of the protocol development process will vary, so order of expected completion is different from the order by prioritization for development.

[b]Lead positions are NPGN I&M core staff unless otherwise noted. Ecologist = General/Aquatic Ecologist.

[c]These protocols are partially or mostly focused on summarization, analysis, and reporting of data obtained through ongoing monitoring by other programs.

Sampling schedules for some NGPN protocols include year-round or seasonally continuous automated monitoring. Most nonautomated field sampling occurs in late spring through late summer (Figure 9-1). For example, vegetation sampling will move from south to north across the Network each year to match phenologic patterns and to minimize the need for repeated visits to remote parks within a year. In contrast, woody sampling is not tied strong to seasonal phenology; sampling for trees and tall shrubs at Black Hills parks may occur during spring and late-summer "shoulder" seasons before and after the narrow seasonal window for sampling herbaceous vegetation. For other protocols, sampling schedules will be adjusted as protocols are developed.

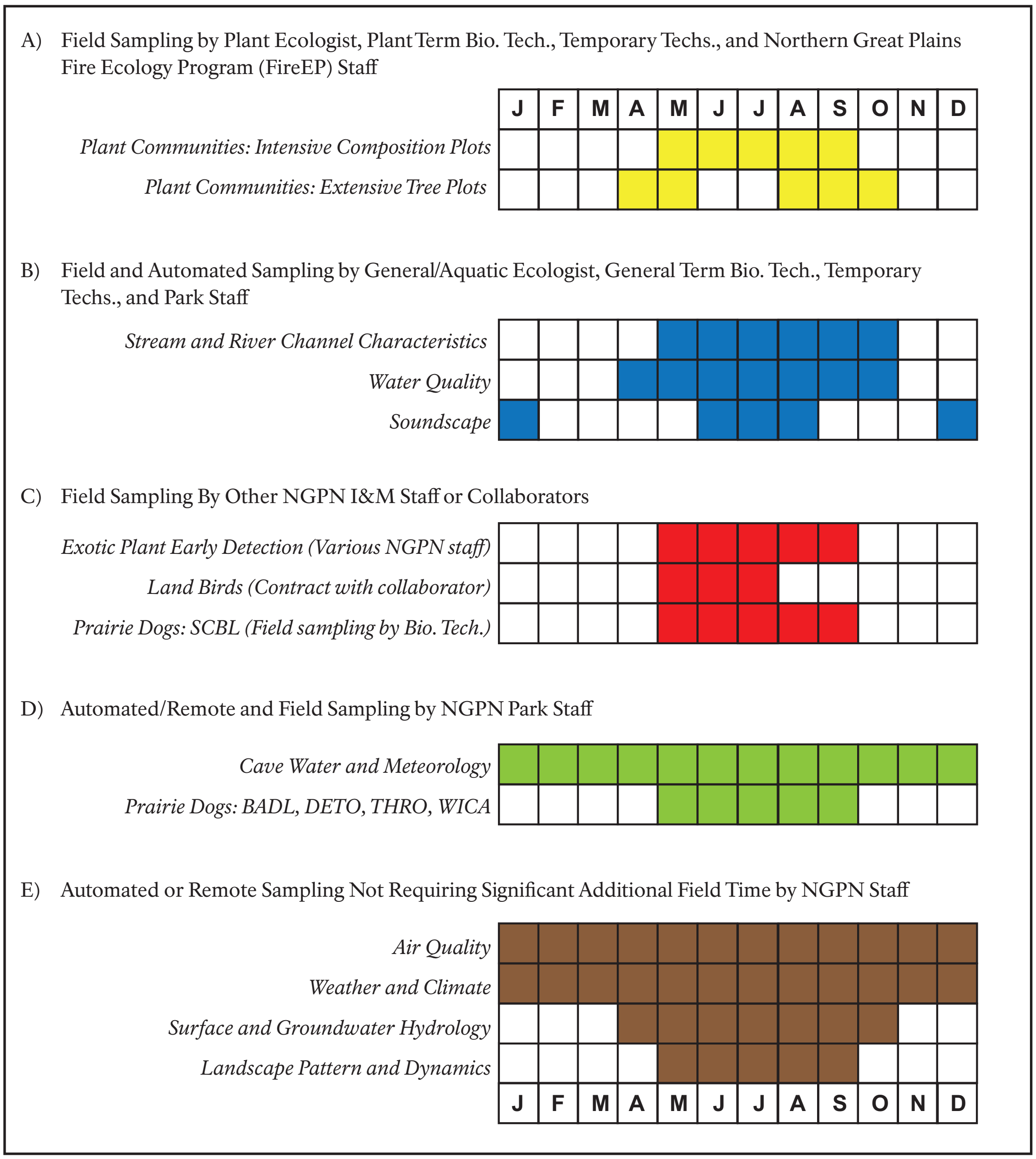


Figure 9-1. Tentative annual sampling schedule for NGPN protocols.

A development or sampling schedule has not been specified for two other protocols (Night Sky and Viewscape; Chapter 5). For other protocols under development, our objectives at selected parks may be limited to summarization and reporting of data collected by others. However, as resources permit and collaborative opportunities become available, we may work with parks and other NPS programs to examine the feasibility of expanding our objectives and developing additional protocols. For example, during FY2008–2010 we are collaborating with the NPS Air Resources Division, USGS, and the South Dakota School of Mines and Technology to assess gaps in current monitoring of ozone, nitrogen deposition, and mercury deposition. In FY2009–2010, staff at Theodore Roosevelt NP will assess possibilities for using inexpensive remote-sensing imagery to monitor size and distribution of active prairie dog towns. This pilot work is critical for assessing what we can afford to monitor, for examining feasibility of alternative monitoring strategies, and for putting ourselves in a position to rapidly develop or expand existing protocols when long term funding is secure for this monitoring.

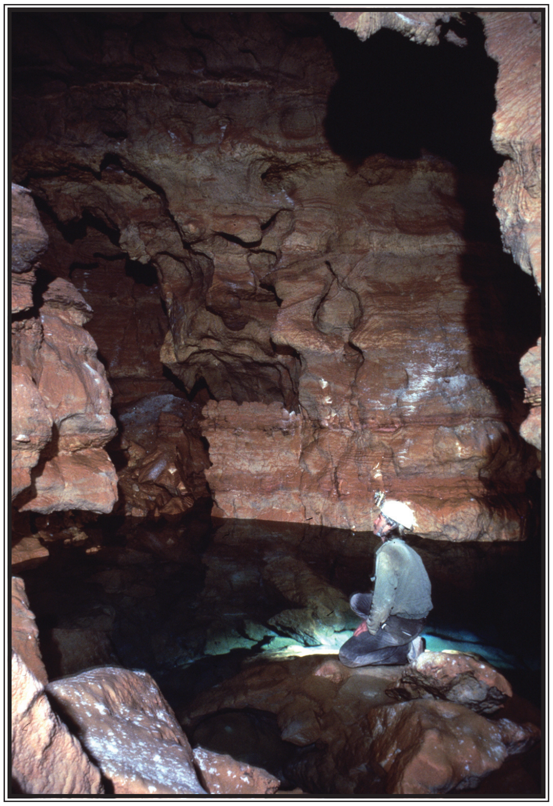
Bison calves at Theodore Roosevelt National Park

Chapter 10
Budget

The NGPN I&M Program is funded from the NPS Washington Office (WASO) Vital Signs Monitoring Program and the Water Resources Division, with expected FY09 funding of $960,700 (Table 10-1) plus congressional increases for inflation. Challenge funds for the program are held in Washington Office base accounts and transferred annually through the Midwest Regional Office. Two Network parks (Agate Fossil Beds and Scotts Bluff NMs) have been conducting monitoring as part of the Prairie Cluster Prototype Program, administered by the Heartlands I&M Network. As of 2010, the NGPN will assume responsibility for Vital Signs monitoring in these two parks, and will receive additional WASO funding for this monitoring.

All NGPN funds are managed by the Network Coordinator under oversight of the Board of Directors. Each year, the program develops an annual work plan (AWP), which must be approved by the Board, the Regional Coordinator, and the National I&M Program Leader. The AWP directs expenditure of funds to salaries, projects, and operations. All I&M Program funds must be strictly accounted for and disclosed in an Annual Administrative Report.

As the Network enters the operational phase of monitoring, personnel costs will be the largest expenditure. The two most expensive protocols (Plant Communities and Water Quality) are both labor-intensive and have high travel costs due to the large size of the Network. Collaborations with other NPS programs will help maximize our efficiency. For example, collaboration with the Northern Great Plains Fire Ecology Program will enable a significant increase in sampling effort and reduction of travel costs for vegetation. For budgetary efficiency and to take advantage of specialized expertise available outside the I&M Program, the Network frequently will establish contracts or cooperative agreements via a Cooperative Ecosystems Studies Unit (CESU) or other mechanisms.



Monitoring water level at Inner Sea lake in Wind Cave, Wind Cave National Park (NPS photo by Jim Pisarowicz, 1986)

The NPS National I&M Program requires at least 30% of the budget be directed toward data management, analysis, and reporting. The Data Manager and Assistant Data Manager positions will spend ~80% of their time on data and information management. In addition to the two dedicated data management positions, all other core I&M staff will spend significant time on these tasks. The Network Coordinator, Ecologists, and biological technicians (permanent, term, and temporary) will spend at least 25–30% of their time on data management and reporting.

Table 10-1. Summary of the NGPN I&M Program budget.

Approximate budget allocations for a typical year, once the initial set of protocols have been completed and operational monitoring has begun.

Income	Source	Amount ($)	Percentage of Total	Total ($)
	Vital Signs Monitoring	768,000	77	
	Monitoring at AGFO/SCBL	150,000	15	
	Water Resources Division	77,000	8	995,000
Expenditures	**Budget Category**	**Amount ($)**	**Percentage of Total**	**Total ($)**
	Personnel (# positions)	694,000	70	
	Permanent staff (7)	517,000	52	
	Term (2)	105,000	11	
	Temporary (~9)	72,000	7	
	Cooperative Agreements	50,000	5	
	Contracts	40,000	4	
	Operations and Equipment	62,500	6	
	Travel	55,000	6	
	Other	87,500	9	
	Office Rent	65,000	7	
	Other	22,500	2	989,000

Chapter 11
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Glossary

Adaptive management: a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Its most effective form, "active" adaptive management, employs management programs designed to experimentally compare selected policies or practices by implementing management actions explicitly designed to generate information to evaluate alternative hypotheses about the system being managed.

Attributes: any living or nonliving feature or process of the environment that can be measured or estimated and provides insights into the state of the ecosystem. The term Indicator is reserved for a subset of attributes that is particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2003). See Indicator.

Co-location: Sampling of the same physical units in multiple monitoring protocols.

Conceptual models: purposeful representations of reality that provide a mental picture of how something works to communicate that explanation to others.

Co-visitation: simultaneous sampling of co-located sampling units; data for multiple monitoring protocols are collected at the same time.

Drivers: major external driving forces that have large-scale influences on natural systems. Drivers can be natural forces or anthropogenic.

Ecological integrity: a concept that expresses the degree to which the physical, chemical, and biological components (including composition, structure, and process) of an ecosystem and their relationships are present, functioning and capable of self-renewal. Ecological integrity implies the presence of appropriate species, populations, and communities and the occurrence of ecological processes at appropriate rates and scales as well as the environmental conditions that support these taxa and processes.

Ecosystem: "a spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries" (Likens 1992).

Ecosystem drivers: major external driving forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that have large-scale influences on natural systems.

Focal resources: park resources that, by virtue of their special protection, public appeal, or other management significance, have paramount importance for monitoring regardless of current threats or whether they would be monitored as an indication of ecosystem integrity. Focal resources might include ecological processes such as deposition rates of nitrates and sulfates in certain parks, or they may be a species that is harvested, endemic, alien, or has protected status.

Indicators: a subset of monitoring attributes that are particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2003). Indicators are a selected subset of the physical, chemical, and biological elements and processes of natural systems selected to represent the overall health or condition of the system.

Inventory: an extensive point-in-time survey to determine the presence/absence, location, or condition of a biotic or abiotic resource.

Measures: specific feature(s) used to quantify an indicator, as specified in a sampling protocol. For example, pH, temperature, dissolved oxygen, and specific conductivity are all measures of water chemistry.

Metadata: data about data. Metadata describes the content, quality, condition, and other characteristics of data to help organize and maintain an organization's internal investment in spatial data, provide information about an organization's data holdings to data catalogues, clearinghouses, and brokerages, and provide information to process and interpret data received through a transfer from an external source.

Monitoring: collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective (Elzinga et al. 2001). Detection of a change or trend may trigger a management action, or it may generate a new line of inquiry. Monitoring is often done by sampling the same sites over time, and these sites may be a subset of the sites sampled for the initial inventory.

Northern Great Plains Network (NGPN): includes 13 constituent parks, their staffs, NPS staff stationed with the NGPN I&M office in Rapid City (I&M core staff), and other NPS and non-NPS collaborators developing and implementing the NGPN long-term monitoring and inventory program.

Northern Great Plains Network (NGPN) I&M core staff: NPS employees whose primary duties focus on NGPN I&M efforts, through funding granted to the NGPN for this program. This term distinguishes these staff from NGPN staff members who are integral parts of the NGPN I&M Program but who are funded from other sources and whose primary duties deal with park management or other tasks.

Protocols: detailed study plans that explain how data are to be collected, managed, analyzed and reported and are a key component of quality assurance for natural resource monitoring programs (Oakley et al. 2003).

Revisit design: schedule for visiting and measuring sample units (monitoring sites) across years.

Sampling design: method of choosing monitoring sites from the target population within each park and the schedule for collecting data from these sites.

Sample frame: collection of sample units (e.g., potential monitoring sites) from which we choose a subset of units where we will collect data. The sample frame also can contain supplemental information about each sample unit, such as its size and location.

Status: the quantitative condition of a park resource at a single point in time or over a temporal window (e.g., mean plant species richness or proportion of sites with >25% non-native cover this year or over the previous 5-year window).

Stressors: physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive (or deficient) level (Barrett et al. 1976:192). Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. Examples include water withdrawal, pesticide use, timber harvesting, traffic emissions, stream acidification, trampling, poaching, land-use change, and air pollution.

Target population: collection of resources or area within each park about which we wish to make statistical inference from the data we collect.

Trend: directional change measured in resources by monitoring their condition over time. Trends can be measured by examining individual change (change experienced by individual sample units) or by examining net change (change in mean response of all sample units).

Vital Signs: as used by the National Park Service, a subset of physical, chemical, and biological elements and processes of park ecosystems selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The monitored elements and processes are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).

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